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THE EMBRYOLOGY OF VERTEBRATE PIGMENT CELLS

PART I. AMPHIBIA

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THE present review has as its aim the consideration of evidence, particularly that of an experimental nature, which relates to the origin of the pigment cells in the vertebrate embryo. However, fully acceptable proof of their source is available in only two groups, the amphibians and birds. Accordingly, attention will be centered on the more recent experimental studies in these classes, except in regard to the work of earlier authors whose opinions have considerable historical interest. The principal consideration will be directed to those recent investigations which have given us information about the migration of the pigment cells, their dependence on extrinsic factors for the production of pigment and the factors concerned in the establishment of color patterns.

While pigment granules may occur in other cells, for example, in ordinary epidermal cells of many forms, in leucocytes, liver cells, etc., the term pigment cell or chromatophore refers to the specialized highly-branched cells typically packed with pigment granules. It is beyond the scope of this review to discuss the phenomenon of color change except to point out that it is brought about by aggregation or expansion of the pigment granules within the specialized pigment cells. This remarkable ability of the lower vertebrates to change color was, of course, known to the ancients and has been the subject of a large number of papers since the time of Pliny, who described the practice at Roman banquets of plunging living mullet into hot water; in dying they exhibited a beautiful play of color (cited from Ballowitz, 1913).

FORM AND DISTRIBUTION OF PIGMENT CELLS

Vertebrate chromatophores typically possess a central mass of cytoplasm containing the nucleus and a considerable number of protoplasmic extensions which branch repeatedly into delicate terminal twigs. In general the pigment is contained both in the central mass and in the cytoplasmic extensions except in states of "contraction" when the pigment particles aggregate in the body of the cell. The pigment may be in solution in the cytoplasm of the cells or in the form of particulate inclusions such as rods, granules or crystals.

Melanophores, cells with brown to black melanin granules or rods, are found in every class of vertebrate. Xanthophores (containing a yellow pigment in solution), allophores (red pigment in solution), guanophores (guanin crystals), iridiocytes (inorganic salt crystals) and xantholeucophores (crystals and a soluble yellow pigment) are less widely distributed among the vertebrates. One somewhat paradoxical cell similar in form to the other pigment cells was discovered by Schuberg (1903) in the dermal and subcutaneous tissues of the axolotl. These interesting cells sometimes contain pigment in varying amounts, but are usually packed with colorless granules. Schuberg termed them *"farblose Pigmentzellen"*. These colorless pigment cells assume a new importance in view of recent work and it may be that they are identical to the dependent or potential pigment cells distinguished by DuShane (1935) in amphibia and by Hamilton in the chick (1940). Elias (1939) has described colorless pigment cells in the toad,

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Bombinator pachypus, but these seem to have a connective tissue function.

Weidenreich (1912), in a thoughtful article, emphasized the distinctive characteristics of pigment cells. Not only are they more highly branched than any other cells, but they have a pronounced tendency to spread out into broad anastomosing sheets definitely localized in the body. In some instances, at least, they are innervated, a fact which immediately sets them apart from leucocytes with which they have often been confused.

The great majority of investigators have directed their attention to the pigment cells of the skin, but cells of similar character occur elsewhere in the body. Numerous authors have pointed out the close relation of chromatophores to blood vessels everywhere in the body, especially in lower vertebrates (see particularly Fischel, 1920), to the peritoneum, mesenteries, and viscera and to the central nervous system (Bolk, 1908, 1910, in teleosts; and Weidenreich, 1912, in all classes of vertebrates). Weidenreich (1912) in his broad consideration of the distribution of pigment cells in vertebrates distinguished the following sites where they tend to be found:

1) a cutaneous layer, subdivided into epidermal and dermal layers;

2) a perineural or epineural sheet surrounding the central nervous system;

3) a pericoelomic layer surrounding the body cavity;

4) a perivascular layer in the coats of the blood vessels.

As he indicated, all of these layers may be present in the lower vertebrates. Thus, there is an outer double coat in the skin which surrounds the several deeper coats of pigment. In higher forms there has been an extensive reduction of the deeper layers and retention of the cutaneous and, in part, the perineural layers.

Elias (1939) in a comparative study of the chromatophores of the skin in amphibians has introduced a more elaborate terminology. He finds that the adepidermal melanophores (dermal melanophores of most authors) have changed from typical pigment cells in the urodeles to colorless cells in the discoglossid toads. These cells which have lost their chromatic function have, in his opinion, acquired a new function as important supporting elements of the skin.

In the following discussion it will suffice to use a somewhat simpler terminology than that of Weidenreich or Elias. Chromatophores will be referred to according to their locations in the body as epidermal, dermal (including subcutaneous cells), and visceral. The latter term will include all deeper pigment cells (Weidenreich's perineural, pericoelomic, and perivascular layers).

ORIGIN OF PIGMENT CELLS

The extensive literature on the origin of the vertebrate pigment cells is reviewed by Fuchs (1914) and Biedermann (1926, 1928, 1930). It is sufficient for our purposes to outline the various sources which have been suggested. A sharp distinction has been made by many between the dermal and epidermal pigment cells. Accordingly, these are discussed separately.

DERMAL PIGMENT CELLS

The four principal views as to the origin of the pigment cells of the dermis and subcutaneous tissue are outlined below.

1a) Leydig (1857, 1876) and the great majority of subsequent workers have thought that they were merely modified connective tissue cells. Among those who have supported this opinion are Kölliker, 1887; Rabl, 1894; Eycleshymer, 1906; Fischel, 1920; Schmidt, 1920; Schnakenbeck, 1921; Berweger, 1926; Elias, 1931, 1934. This conception obviously implies that the chromatophores are of dermal origin.

1b) Rabl (1889, 1894, 1896), Erhmann (1896), and Schuberg (1903), while agreeing that the chromatophores were of mesodermal (i.e. dermal) origin, regarded them as cells of a special sort rather than modified connective tissue cells. Perhaps this somewhat different concept may be best expressed in translation from Ehrmann. The chromatophores are "cells *sui generis* which are neither identical to connective tissue cells, nor to leucocytes, nor to epidermal cells." Ehrmann accordingly named them melanoblasts, a name which has unfortunately been extended by Bloch (1917) to any cells capable of synthesizing pigment, rather than retained as a designation for prospective pigment cells.

2) Aeby (1885) in a study of the development of pigment in the skin of birds and mammals came to the opinion that pigment cells were wandering cells (leucocytes) which phagocytosed red blood cells and then transmitted the resulting pigment granules to the epidermal cells as nutritive material (*Bau- und Nährstoff*). Meyerson (1889) and List (1890) took a similar view. Rabl (1896) thought that while the dermal pigment cells were modified

connective tissue cells, the epidermal chromatophores were leucocytes.

These interpretations are readily understood in view of the evidence that has accumulated in regard to pigmented leucocytes in the amphibia in particular. Thus, Schuberg (1903), Schmidt (1920), and Elias (1931) found pigmented leucocytes in the epidermis. Schmidt and Elias both described phagocytosis of pigment from the epidermal cells by leucocytes. The latter authors, however, did not confuse these cells with the specialized pigment cells. In a careful study of the fate of extruded erythrocytes in the tails of living tadpoles, Clark and Clark (1926) observed large pigmented, wandering cells in the act of phagocytosing red blood cells. They consider these to be the morphological and physiological equivalent of "the mammalian cells which have been variously designated as clasmatocytes, macrophages, endothelial leucocytes, histiocytes, pyrrhol cells, etc." These pigmented leucocytes are probably unrelated developmentally to the chromatophores, but have proved a source of considerable confusion in the study of the latter.

3) Kodis (1889), Jarisch (1892), and Kreibich (1913), among others, were of the opinion that the first pigment cells appeared in the epidermis as modified epidermal cells and thence some of them migrated into the dermis to become dermal chromatophores.

4) Borcea (1909) and Weidenreich (1912) suggested the origin of the chromatophores from the embryonic neural crest in teleosts and amphibia respectively. All recent evidence supports this conclusion and it is discussed in detail below.

EPIDERMAL PIGMENT CELLS

The controversies as to the origin of the epidermal chromatophores have followed a similar pattern. Thus, Kodis (1889), Mertsching (1889), Jarisch (1891), Mayer (1892), Kromeyer (1893), and Schwalbe (1893) regarded them as derivatives of epidermal cells. Eycleshymer (1906) in a study of *Necturus* embryos alive and in sections thought that some of the epidermal pigment cells may have been transformed epidermal cells and that others migrated from the dermis. The latter migration was observed in living embryos. Eycleshymer, studying embryos of *Necturus* alive and in sections, observed that some epidermal pigment cells became pigmented *in situ*; others migrated from the dermis to become epidermal chromatophores. He points out that the former may have migrated earlier as colorless cells or that they may have been formed from epidermal cells. Ehrmann (1892) thought that some may have been formed by transformation of epidermal cells, although the majority were derived from the dermis. Fischel (1920) and Schnakenbeck (1921), studying amphibia, figured all stages in the transformation of epidermal cells to epidermal pigment cells. More recently, Stone (1933), in a study of the lateral line, observed the transformation of an epidermal cell into a pigment cell.

Aeby (1885) and Rabl (1894) regarded the epidermal chromatophores as leucocytes of mesodermal origin (see above).

The greater number of investigators support the view that the dermal and epidermal pigment cells have a common origin as modified connective tissue cells or at least as cells of mesodermal origin. The principal proponents of this view are Kölliker (1887), Erhmann (1892, in large part), Eycleshymer (1906, in large part), Schmidt (1920), Berweger (1926), and Elias (1931). In a more recent paper Elias (1934) regards the origin of the epidermal pigment cells as uncertain.

Aside from the direct observations which seem to show the transformation of an ordinary epidermal cell into a pigment cell, there is only fragmentary evidence as to their origin. These cells have been neglected in recent experimental work, but DuShane (1935) noted their absence after removal of the neural crest and pointed out that this was suggestive of their origin from that source. The positive experiments, i.e. transplantation of neural crest, have not given a decisive answer to this question. However, the fact that they appear in ventral epidermis of *Amblystoma punctatum*, transplanted to the flank of the white axolotl, seems also to support the view that they originate in common with the dermal chromatophores.

Weidenreich (1912) thought all pigment cells were related elements derived from the neural crest. The more recent results bearing on this hypothesis are discussed below.

THE NEURAL CREST THEORY OF PIGMENT CELL ORIGIN

During the last decade transplantation and explantation experiments on embryos have shown beyond question that the dermal, subcutaneous, and visceral pigment cells of two distantly related verbebrate classes, amphibians and birds, originate from the embryonic neural crest. From this site

of origin immediately dorsal to the neural tube they appear to migrate as colorless ameboid cells into all regions of the body which subsequently become pigmented.

In view of the numerous investigations, some of which are mentioned above, it is, at first glance, astonishing that this source of the pigment cells so long escaped discovery. From the vantage point of our present knowledge of the origin of these cells, it is possible to understand the failure of the earlier investigators. Without exception the early studies directed specifically to the problem of pigment cell origin were based upon the traditional methods of embryological study, that is, the microscopic study of serial sections. With the exceptions of Borcea (1909) and of Weidenreich (1912), all of those using this time-honored approach, failed to suggest the neural crest origin of the chromatophores.

To the great majority of investigators, the chromatophores appeared to develop either in the connective tissue beneath the epidermis or in the epidermis itself. The possibility of their migration from the one layer to the other as colorless cells was not entirely overlooked (see above). However, the earlier migratory stages of colorless prospective pigment cells generally escaped observation. It is of interest to examine the exceptions to this statement. It should perhaps be borne in mind that these papers were overlooked by most subsequent writers on the subject of pigmentation.

The earliest statement which may be interpreted as linking the pigment cells to the neural crest was made by Borcea (1909) in a brief unillustrated report. Citation of this paper by Fuchs (1914) saved it from total obscurity. Borcea studied bony fish embryos of several species, particularly *Belone acus*. In regard to this species he stated that pigment cells were of ectodermal origin and that in embryos three days old (in free translation)

> on each side of the nerve cord, between it and the epidermal layer, one sees cells which detach themselves and migrate into the interstices of organs already formed; some migrate between the nerve cord and somites arriving at the surface of the intestine; a much smaller number passes to the lateral side of the somites, covers over the lateral plate and reaches the surface of the yolk sac. On the sixth day the cells begin to show pigment granules.

From this statement it is clear that Borcea traced the origin of the pigment cells to the neural crest and could recognize them before the development of pigment. He further points out that in "pelagic eggs with very rapid development (*Uranoscopus scaber* L.; *Fierasfer acus* Brünn; *Labrax lupus* Cuv.) these cells appear at the end of the first day of development and are already loaded with pigment even at the time of separation." These latter forms were obviously particularly favorable for the study of this question, since this description makes it clear that they were pigmented while still in contact with the nerve cord and epidermis. In most vertebrates, as in *Belone acus*, the pigment develops only after the cells have reached their definitive positions.

Quite independently, Harrison (1910), in his classic paper dealing with the outgrowth of nerve fibers in tissue culture, suggested a similar origin. He found pigmented cells in cultures of the spinal cord of frog embryos and expressed the possible rôle of the neural crest in the following way:

> While the evidence is by no means conclusive, especially since no great care was taken to exclude the presence of mesenchyme cells, the fact that pigment cells were frequently formed from these pieces of medullary cord suggests the possibility that these cells may normally take origin in part from this source, most likely from the ganglion crest. This suggestion is borne out by the fact that pieces of the medullary cord or cranial ganglia when transplanted to various regions of the embryonic body often break down and give rise to large numbers of pigment cells.

This prophetic observation was first cited by DuShane (1935) and consequently failed to enter the literature on pigmentation until a late date.

In 1912, Weidenreich, with no awareness of the brief note by Borcea or the casual observation by Harrison, gave the fullest expression to the neural crest hypothesis of pigment cell origin. He had been impressed by the characteristic location of pigment cells in close relation to the neural tube and the dorsal region of the body in a variety of embryos (*Petromyzon*, *Salamandra*, *Triton* and *Rana*). His view may be best expressed in a free translation of his own words:

> It is not possible for me to render a definite judgment here concerning the origin of the chromatophores, since I have not been able to bring my investigations to a successful conclusion owing to the lack of the proper developmental stages and of embryos suited to this purpose. I should, however, like to give expression to the conception of their origin which appears to me to be most likely according to my observations. It seems to me as though the pigment cells are of ectodermal origin

and that they free themselves from the cell mass at the point of closure of the neural tube precisely as does the neural crest and from here migrate out into the embryo along definite paths; the elaboration of pigment first occurs after the cells have reached their definitive positions. I emphasize that the anatomical proof for my conception is still lacking and that it must meanwhile be regarded as a working hypothesis.

That it was more than twenty years before the "anatomical proof" for his remarkable deductions was forthcoming may be attributed to the well-entrenched view that the pigment cells were mesodermal elements. Weidenreich's paper is cited by numerous authors in regard to some of his other contentions, but except for citation by Fuchs (1914) and Fischel (1920) the radical hypothesis he advanced was not mentioned. It is interesting that the latter author dismisses this hypothesis as quite unlikely in the following words in reference to Weidenreich (p. 127): "Er spricht ferner die—wir mir sehr unwahrschleinliche—Vermutung aus, dass sich diese Zellen sämtlich aus der Verschlussgebietes des Neuralrohres, ähnlich den Zellen der Nervenleiste, ablösen und dann im Organismus auf bestimmten Bahnen ausbreiten."

Mangold (1929), unacquainted with the suggestions mentioned above, comes close to a solution of the problem. He noted that the prospective medullary plate of late gastrulae of *Triton* when transplanted gave rise to a complex of neural tissue and melanophores, while in those instances in which neural tissue failed to differentiate, melanophores were lacking. Pieces of presumptive brain including the medullary folds of late neurulae, transplanted to the blastocoel of gastrulae, develop melanophores before melanophores appear above the brain of the host. On the other hand presumptive epidermis from a gastrula or neurula does not produce melanophores when transplanted in a similar way. In an earlier publication, Mangold (1923) had already noted that presumptive medullary plate from a gastrula accumulates melanophores about it when transplanted to the belly (cf. Harrison, 1910). Mangold draws other examples from the literature. Spemann (1901, 1902, 1903) found that the two halves of frontally constricted gastrulae of *Triton taeniatus* would develop as one normal embryo and a vesicle. Typically the vesicle developed from the ventral half of the embryo lacked a neural axis and pigment. Mangold and Seidel (1927) found that some of the vesicles derived by constriction in this way developed small pigmented tails which were found to contain traces of the axial system including the neural tube.

Considering all of these results together Mangold (1929) pointed out that a definite relationship between the formation of melanophores and the medullary plate was indicated.

Holtfreter also in 1929 observed that presumptive medullary plate from a *Triton* gastrula placed in the mesenchyme of a *Hyla* tadpole developed melanophores and that these then could be seen to migrate away from the graft beneath the transparent epidermis of the host. In an extensive work dealing with the influence of host age and body region on the differentiation of transplanted gastrula ectoderm, he performed a decisive experiment. In this paper (1933) he found that when the neural plate of an axolotl neurula was removed and the neural folds left in place, two dorsal fins develop with normal distribution of the melanophores; on the other hand if neural folds and neural plate were removed together, no melanophores appeared in the later embryo. He further showed that melanophores developed in implants of gastrula ectoderm in which only mesectodermal derivatives of the medullary plate were induced and in which no nervous tissue appeared. This indicated that pigment cells can be induced to form without the simultaneous induction of neural tissue and led him to advance the statement that the pigment cell primordium most likely occurs in neural folds in common with that of the ganglion crest.

The complete proof of the neural crest origin of pigment cells was established by a variety of transplantation, explantation, and deficiency experiments on urodele amphibians (several species of *Amblystoma*) by DuShane (1934b, 1935, 1938). The primordia of the neural crest in the future trunk region were eliminated by removing appropriate portions of the neural folds from embryos of *Amblystoma punctatum* and *tigrinum* at the open neural plate stage. Following this removal, the embryos developed normal pigmentation in the head and tail, but totally lacked skin and visceral chromatophores, melanophores, xanthophores, and guanophores in the trunk region (Fig. 3a). This alone, in conjunction with the slightly different experiment of Holtfreter cited above, strongly indicated a neural crest origin for the pigment cells. Study of the embryos in section (DuShane,

1938) showed that not only were pigment cells of all types lacking, but that the embryos were also deficient in the same region in spinal ganglia and Rohon-Beard cells. This further deficiency confirmed the efficacy of the operation in entirely eliminating the neural crest. Supporting evidence was obtained by explanting the same sections of the neural folds into salt solution by the method of Holtfreter (1931). All explants of this type gave rise to melanophores within six days of the time of explantation. Of twenty pieces of flank ectoderm and mesoderm taken immediately lateral to the neural folds in embryos of the same stages only one developed melanophores. In the exceptional case it is quite likely that a part of the crest primordium was included, since the cuts passed close to the neural fold.

Transplantation of the neural crest and a narrow strip of the overlying ectoderm from embryos of *A. punctatum* to *A. tigrinum* and in the opposite combination gave an unequivocal result. Pigment cells (xanthophores and melanophores) of donor, not host type, invariably developed in the region of the transplant and laterally on the flanks (Fig. 1b). Likewise, similar transplants or neural fold grafts to the abdomen, a site where melanophores and xanthophores normally do not appear, gave rise to xanthophores and melanophores which spread from the graft. Some further less direct evidence of their origin from the ganglion crest was obtained by grafting limb primordia or flank ectoderm and mesoderm between the same two forms. Limb anlagen or flank ectoderm and mesoderm pieces transplanted at early tail bud stages acquired host pigmentation; at late tail bud stages they developed donor pigmentation. This result, which is discussed more fully below, was taken as evidence of the migration of the chromatoblasts into the limb or flank mesoderm at a stage later than that of the early operation and prior to that of the older operation. Similar results followed explantation of flank ectoderm and mesoderm into salt solution. Melanophores developed only in those derived from older embryos (Harrison stage 32 or older in *A. punctatum*).

These results taken together constitute complete proof of the origin of the chromatophores in the trunk region from the neural crest. More recent work confirms this conclusion.

Twitty (1936) transplanted the neural crest and overlying epidermis between different species of *Triturus*. In all instances the melanophores were clearly of graft origin (Figs. 2a, 2c). Raven (1936) in transplantations of neural folds from the axolotl to *Triton taeniatus* found large pigment cells beneath the skin and around the neural tube. These he interpreted as being of axolotl type and hence of neural crest origin. In further studies Raven (1937) grafted the floor of the neural plate in the same combination. The axolotl cells have larger nuclei than those of *Triton* and hence can be identified in many tissues. In the case of melanophores, however, the pigment granules are so abundant that nuclear measurements are impossible. Raven found large pigment cells immediately around the neural tube in the region of the graft, and, judging by their size, he concludes that "these cells are probably axolotl cells originating from the graft; however, owing to the impossibility of measuring them, this could not be proved with certainty." He adds that if "these cells are really derived from the graft, it must be inferred that melanophores not only arise from the neural crest . . ., but also from the ventral part of the neural tube." This evidence, weak at best, is controverted by experiments involving removal of the neural folds while the major part of the spinal cord was left intact. In no instance have any pigment cells developed in the region of operation (DuShane, 1935, 1938; Harrison, 1938; Bytinski-Salz, 1938). It is much more likely that the host pigment cells in Raven's cases were stimulated to produce more abundant pigment by their close relationship to the axolotl tissue of the cord. Such influences of surrounding tissues are fully discussed in a succeeding section.

Bytinski-Salz (1938) in extirpation, isolation, and xenoplastic transplantation experiments on the toad, *Bombina pachypus*, showed that pigment cells of all types in the head as well as in the trunk were of neural crest origin. Baltzer (1941b) has confirmed the origin of all types of chromatophores from the neural crest in anura by transplanting neural folds from *Hyla* to *Triton* and the axolotl. The grafted tissue gives rise to typical *Hyla* melanophores and guanophores which persist for approximately two months in the host.

It is of some interest that Holtfreter (1935b) in studying the differentiation of *Triton* gastrula ectoderm grafted to *Hyla* tadpoles found that neural crest derivatives, including chromatophores, could be induced to form from the indifferent ectoderm.

Twitty and Bodenstein (1939) found striking pigmentary differences in graft and host regions in combinations of *Triturus torosus* hosts with *Amblystoma tigrinum* neural crest. These results

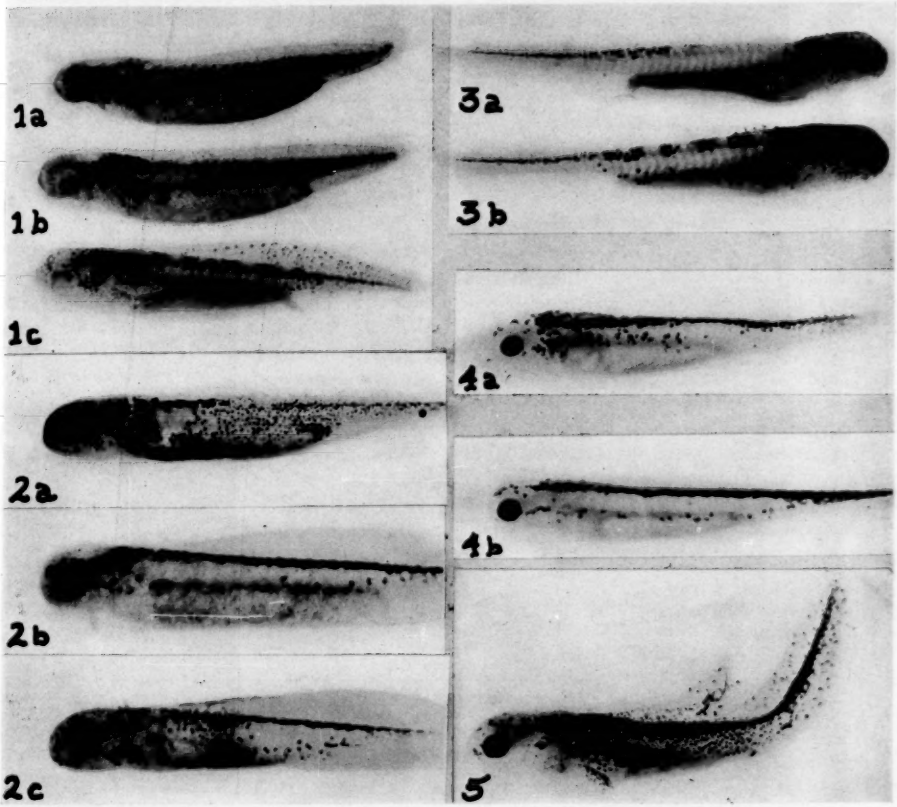


PLATE I

FIG. 1. (a) Normal control embryo of *Amblystoma punctatum* from the same egg mass as (b), an embryo whose trunk neural folds were replaced by those of *A. tigrinum* at stage 16 (neurula) on April 1, 1936. (c) *tigrinum* control embryo. Note the *tigrinum* melanophores on head and trunk of (b). Photo, × 6, before reduction, April 7, 1936. Original.

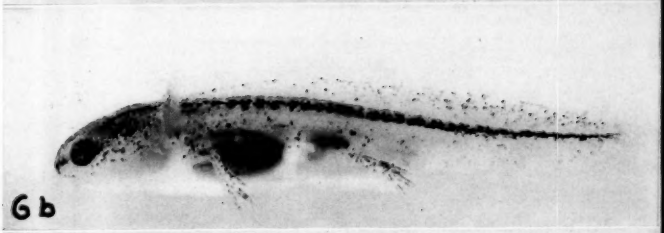
FIG. 2. (a) *Triturus rivularis* embryo with transplanted neural crest and ectodermal strip from *T. torosus* in the trunk region. The donor melanophores are situated in the anterior trunk region and show the donor pattern dorsally. The graft melanophores have spread somewhat further ventrally than in the normal donor control embryo, *T. torosus* (b). (c) *A torosus* embryo with trunk graft of *rivularis* neural crest. The *rivularis* (graft) melanophores in the trunk have the normal donor pattern. Published by the kind permission of Dr. V. C. Twitty.

FIG. 3. (a) *A tigrinum* embryo from which the neural folds were removed in the neurula stage on Jan. 24, 1936. The absence of melanophores in the trunk dorsally and laterally is obvious in comparison with the control embryo (b). Photo, × 6, before reduction, Feb. 3, 1936. Original.

FIG. 4. (a) *T. torosus* to which one neural fold of *A. tigrinum* was grafted on Jan. 24, 1936; the host fold of the opposite side was left intact. (b) Normal *torosus* control. Photo, × 6, before reduction. Original. Feb. 10, 1936. The graft melanophores may be seen on the flank and head; along the dorsal line they intermingle with host melanophores derived from the neural fold left in place.

FIG. 5. *T. torosus* embryo to which both neural folds of an *A. punctatum* neurula were grafted at stage 16 on March 12, 1936. Photo, × 6, before reduction, April 7, 1936. The melanophores of the donor populate the entire trunk from head to tail and have spread into the gills and fore limbs and ventral on the flanks. Compare with Fig. 4b, a normal *torosus* embryo. Original.

6a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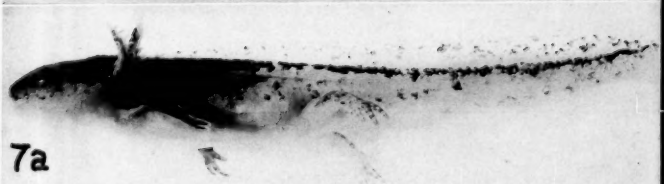
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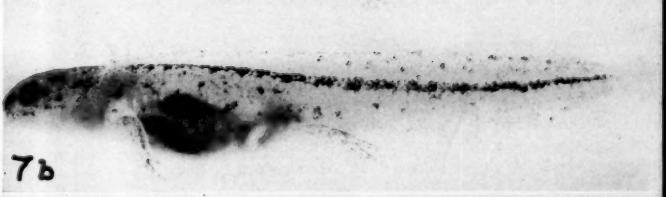
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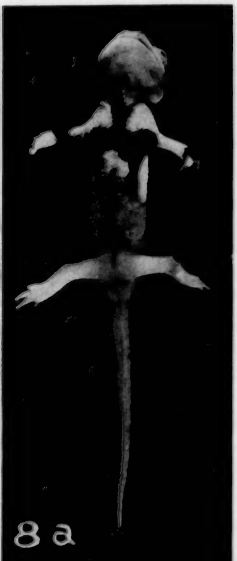
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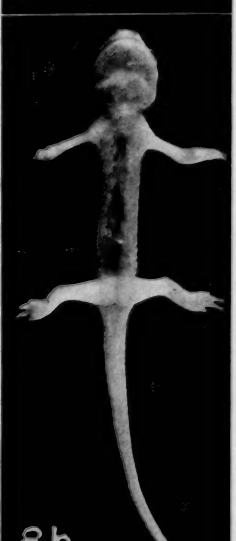
8b

are similar to those illustrated by Figs. 4a to 8b which represent operations of this type done by the writer in 1936 and not previously published. In these operations both neural folds were grafted in neurula stages. The differences in pigmentation between controls (b in the figures) and animals bearing a *tigrinum* graft (c in the figures) are striking.

PIGMENTARY PATTERNS IN AMPHIBIA

The origin of pigment cells from the neural crest implies that they must migrate for greater or lesser distances in the embryo to reach their definitive positions. It is clear from their distribution in larval amphibians that some migrate only a short distance or not at all while others spread laterally beneath the epidermis or ventrally around the neural tube and notochord. In some instances a rather uniform distribution of the skin pigment cells results; in others the cells accumulate at certain levels of the flank to form lines or aggregate to form conspicuous spots. Differential migration of the prospective chromatophores is thus an important factor in setting up the larval and adult patterns of pigmentation.

Differential migration alone will not account for the final pattern. There is considerable evidence that at least in some embryos not all of the prospective pigment cells complete their differentiation. There is then a reservoir of cells which fail to synthesize pigment. These are perhaps identical to the colorless pigment cells of Schuberg (1903). Under certain experimental conditions or during metamorphosis many of these cells rapidly develop melanin. Some progress has been made in the analysis of the factors which influence melanin formation in these potential melanophores.

MIGRATION AND AGGREGATION OF PIGMENT CELLS

The melanophores and xanthophores of *Amblystoma punctatum* distribute themselves uniformly over the dorsal and lateral sides of the head and trunk; those of *A. tigrinum*, however, aggregate to form conspicuous groups of cells. When the prospective pigment cells of *A. tigrinum* were transplanted to the embryos of *A. punctatum* in the normal position, the resulting pigmentation of the region of the trunk affected by the graft was

PLATE II

FIG. 6. (a) *T. torosus* larva to which the left neural fold of an *A. tigrinum* neurula was grafted orthotopically on Jan. 27, 1936 at stage 16. The right neural fold was left in place. Photo, × 3.8, before reduction, April 23, 1936. Original. This animal, like most of the others in the series of 18 operations, is remarkable in that the graft melanophores have spread far beyond the limits of the graft. *Tigrinum* xanthophores and melanophores were present in both forelimbs, over the posterior half of the head and the entire trunk, well out onto the tail and in the dorsal fin. The left hind limb showed melanophores of graft type only, while the right limb contained melanophores of both host and donor character. In the living animal, no host melanophores were recognizable in the trunk, posterior part of head or fore limbs. Twitty and Bodenstein (1939) have published somewhat similar figures based on operations at tail bud stages, where the entire crest was transplanted. They regard this as evidence of suppression of the host melanophores by those of *tigrinum* type. They suggest that possibly the host melanophores were phagocytosed by those of the graft, but present no cytological evidence for this opinion. I have studied one animal similar to the one pictured in complete serial sections and find that *torosus* melanophores as well as *tigrinum* melanophores were present. This indicates that the larger more abundant graft melanophores obscure those of the host. Two animals with both folds grafted were carried through metamorphosis, and it is noteworthy that the melanophores of recognizable graft type disappear from the trunk and head and are present only in the region of the graft (Fig. 8a). This phenomenon remains to be explained. Compare to Fig. 6 (b), the control larva.

FIG. 7. (a) Operation as above, except that both neural folds were grafted. The spread of graft chromatophores has been much less extensive, involving only anterior half of trunk, fore limbs and posterior part of head. (b) Control. Operation, Jan. 29, 1936. Photo, × 2.88, June 3, 1936. These animals were carried through metamorphosis and were almost identical to those shown in Fig. 8.

FIG. 8. (a) Operation as in Fig. 7 and on same date. Photo, × 2.1, Nov. 14, 1936, from below. (b) Control. The grafted *tigrinum* pigment cells form a band encircling the young adult in the region of the graft. The spots, characteristic of the donor and the abdominal pigment made their appearance during metamorphosis. Compare with control animal. This animal (8a) during larval life had graft melanophores distributed as in the larva shown in Fig. 6a. However, as metamorphosis was occurring these disappeared except in the anterior trunk region. Original.

FIG. 9. An adult *A. punctatum* showing its normal spots situated dorsally (brilliant yellow in life) and a white axolotl ectoderm and mesoderm graft to the flank. Photo taken 244 days after operation (165 days after metamorphosis). The graft was made when the host was at stage 28 (tail-bud). During larval stages a few large melanophores of host type appeared in the dorsal graft region, but the main area never showed melanophores. The central part of the graft area in the adult remains free of visible melanophores, although there is some encroachment around the periphery. In all probability, potential melanophores are present in the graft but fail to synthesize pigment (see text). Original.

entirely that of the donor (DuShane, 1935). In view of Twitty's work, discussed below, it is clear that here pattern depends not on the special embryonic environment of the chromatophores but upon the intrinsic activities of the cells themselves.

We are indebted to Twitty for a beautiful analysis of the development of pattern in several species of the California newt. This study was facilitated by the discovery of two new species of *Triturus* (*T. similans* and *T. rivularis*, Twitty, 1935, 1942b) which differ in several respects from the older species, *T. torosus*. These species show important differences in pigmentation and in addition are readily hybridized in the laboratory.

In *T. torosus* larvae the melanophores form a distinctive dorsal longitudinal line beneath the epidermis at the level of the dorsal edges of the somites (Fig. 2b). The flank is sparsely populated with melanophores although there is tendency for an ill-defined longitudinal accumulation of cells at the level of the pronephric duct (dorsal boundary of the yolk). Melanophores are lacking below this level in young larvae. In *similans* larvae, the distribution is somewhat modified: the dorsal bands are present but less sharply defined; the ventral accumulation of melanophores is greater and spreads ventrally over the yolk sac. In later stages the melanophores become more diffusely arranged so that the bands are no longer distinguishable. In *rivularis* the pigment cells are diffusely and uniformly distributed over the dorsal and lateral sides of the embryos (Fig. 2a, in the posterior half of the embryo).

By transplanting the neural crest between embryos of these three species, Twitty was able to show that in every combination of transplantation, the pigment cells assumed the pattern of the donor animal. Thus a *rivularis* embryo with *torosus* graft showed sharply defined bands of melanophores dorsally and a weak ventral line in the trunk region affected by the graft (Fig. 2a). On each side of this segment of the trunk the normal diffuse pattern of the host was obvious. The reciprocal combination is illustrated in Fig. 2c, which is a *torosus* embryo with a *rivularis* graft. Thus the prospective pigment cells when grafted into the normal position in an embryo of different species manifest the same migratory ability and the same predisposition to stop at certain definite levels, or, in other instances, the same tendency to spread diffusely over the flank as they would have if left in place in the donor animal. The distributional pattern depends on factors inherent in the cells themselves and not on the specific embryonic environment.

To the analysis of these factors, Twitty directed other types of transplantation experiments. Embryonic ectoderm grafted dorsally between the species had no effect on the development of the dorsal lines or upon their failure to appear. While ectoderm plays an important rôle in melanin formation which will be brought out below, it is clear that within the limits of Twitty's experiments the different ectoderms played no part, or, perhaps better, all played similar parts, in relation to the melanophores.

The primary step was the transplantation of skin, somites, and neural tube of *torosus* embryos to the flank as a unit. In the graft two dorsal bands were formed as in the normal embryo at the point where the somites are in contact with the epidermis. Some remained dorsal to the neural tube as in the normal embryo. When the neural tube, skin, and the somites of only one side were grafted in similar fashion a single dorsal band formed in relation to the somites while the remainder of the pigment cells were associated with the neural tube and irregularly distributed lateral to it. When neural tube with neural crest alone is grafted to the flank, the dorsal bands fail to form and the melanophores remain for the most part in association with the neural tube. When crest cells alone were grafted the pigment cells spread irregularly from the region of the graft, aggregating into small clusters and showing some tendency to follow the dorsal border of the yolk mass.

The somites thus play a major part in the formation of the dorsal bands. The pigment cells of *torosus* may be regarded as having a tendency to aggregate and to be halted in their migration at the point where somites and epidermis meet and again at the border of the yolk mass (pronephric level). They show essentially the same behavior when grafted to other forms. The essential factors in their distribution are thus intrinsic. In a similar way, Twitty interprets the results obtained with the other species. When neural tube and skin of *rivularis* were grafted to the flank the melanophores showed very little tendency to surround the neural tube and a correspondingly great tendency to migrate diffusely away from the graft. This is in contrast to the behavior of the pigment cells of *torosus* which show in Twitty's words "a

pronounced habit of adhering to one another or to any other conveniently situated structure, whether it be neural tube, somites or yolk vessels."

Speaking further of the melanophores of *torosus*, Twitty points out that they possess potentiality for considerable migration and says:

> If, however, we postulate that the pigment forming cells of *torosus* are particularly adhesive in nature, their subsequent behavior becomes much more readily understandable. Their tendency toward migration is held in check not only by mutual adhesion but by a similar affinity for other structures in the immediate vicinity. These are the neural tube itself and the dorsal margins of the somites.

Twitty suggests that gradations of the adhesive tendency or "glutinosity" of the melanophores may account for their different behavior in different species.

That these different properties of the melanophores of various species might be linked to the intensity of their pigmentation was suggested quite tentatively by Twitty (1936). In furtherance of this hypothesis, Twitty and Bodenstein (1939) pointed out that in *torosus* embryos pigment develops rapidly and the melanophores become densely pigmented. In *rivularis* embryos, on the other hand, the melanophores develop pigment relatively slowly and never become as heavily pigmented as those of *torosus*. It will be recalled that in *torosus* the pigment cells have a limited distribution with a strong tendency to aggregate around the neural tube and at the dorsal line; in *rivularis*, on the other hand, they spread diffusely from the source. They are led to suggest that the differences in migration may be associated with the time of onset and the intensity of pigmentation, since the appearance of pigment coincides with the end of the migratory activity. In this connection they adduce the evidence derived from hanging drop tissue culture of the neural crest. Here, as in the normal embryos, pigment appears later in the cells of *rivularis* than in those of *torosus*. Relating these results to the normal pigment patterns, Twitty and Bodenstein say (p. 393): "If migration from the neural crest is indeed eventually halted through changes associated directly or indirectly with the development of melanin, a differential in the activity of pigment formation might well explain specific differences in melanophore distribution." Criticism of this general interpretation is in part reserved for discussion below, but it should be mentioned now that there is no evidence except that from tissue culture to indicate that the fully differentiated melanophore of an embryo has lost the ability to migrate. Under this hypothesis it is, for example, difficult to account for the very wide dispersion of the melanophores of *A. tigrinum* in normal embryos or when grafted to other species (Figs. 4a to 8b, except Fig. 5). The melanophores of this species become pigmented with great rapidity and attain a considerable density of melanin. In summary, this is an enticing hypothesis, but the critical evidence by which its validity may be assessed is not at hand.

Hybridization of the three species of *Triturus* in all possible combinations showed that the pigment cells of any one cross distributed themselves in a pattern roughly intermediate between those of the parent species. From the analysis above, it is fair to assume that the intrinsic characteristics of the hybrid melanophores differ in respect to their tendency to aggregate or to migrate from those of either parent. As in the case of transplantations of neural crest between the species, similar grafts from hybrid to normal embryos resulted in the grafted cells assuming the hybrid (donor) pattern. This bears out the general conclusion that the specific embryonic environment is not of major importance in influencing the distributional pattern of the melanophores.

HOST INFLUENCE

There were, however, certain differences in the distribution of melanophores at the level of the yolk border in graft combinations between *torosus* and either *similans* or *rivularis* which indicated that at this level the host controlled the pattern. In *torosus*, the melanophores are restricted to a narrow region at this level, while in *similans* and *rivularis* they descend below this border. In grafts of *similans* or *rivularis* neural crest to *torosus*, the melanophores do not appear below this border. In reciprocal combinations the melanophores of *torosus* spread over the yolk sac. Thus some influences of the host affect their distribution at this level.

DeLanney (1941) carried the investigation somewhat further by transplanting blocks of somites between *torosus* and *torosus* ♀ × *similans* ♂ hybrid embryos. It is an advantage to use hybrids in this experiment since they are necessarily the same size as the *torosus* embryos and in addition develop melanophores over the sides of the yolk mass. DeLanney's experiments showed

that the mesoderm at the level of the yolk border determined the distribution of the melanophores. In *Torosus* embryos with hybrid graft mesoderm the *torosus* melanophores moved ventrally over the yolk; in reciprocal combinations, they stopped at the yolk border. DeLanney points out that this indicates that the flank mesoderm controls the distribution of the melanophores and suggests that it is possible that *torosus* mesoderm offers "an unfavorable 'terrain' for the migration of prospective melanophores."

Rosin (1940) in transplanting one neural fold from the axolotl to *Triton palmatus* found that the grafted melanophores tend to distribute themselves in the trunk largely according to the host; not the donor pattern. *Triton palmatus* has a general pattern quite similar to that of *Triturus torosus*, consisting of well-marked dorsal lines and an accumulation of melanophores at the yolk border. The sides of the flank are free of melanophores. The axolotl manifests a diffuse pigment pattern with uniform distribution of pigment cells. The grafted axolotl cells, however, are distributed like those of the host, leaving the area of the flank lateral to the myotomes unpigmented. Another instance which illustrates the dominant rôle which may be played by the host in determining pigment pattern is provided by Baltzer (1941b) who transplanted the neural folds from *Hyla* to axolotls and *Triton*. In this instance the grafted melanophores and guanophores migrate extensively and accumulate at the yolk border, thus simulating in part the pattern of the *Triton* hosts. The particular interaction of factors which produces these results has not been analyzed further.

The importance of local factors in determining pattern in another region, the iris, has been disclosed by Barden (1942), who transplanted eye vesicles in several species combinations. The migrant crest cells of the host become the pigment cells of the iris of the grafted eye. In *torosus* the glistening chromatophores are normally restricted to the dorsal and ventral parts of the eye in the adult. A *torosus* eye grafted to a *tigrinum* host reproduces this pattern with *tigrinum* chromatophores, although these normally pigment the iris completely. The results with reciprocal and other combinations are similar: the eye determines the pattern. Barden suggests as the most probable explanation that only the potential pigment cells which come to lie in the dorsal and ventral quadrants of the *torosus* or *rivularis* eye develop into typical chromatophores. That potential (or colorless) chromatophores may be present in all parts of the iris in these species is indicated by their occasional faint visibility in the quadrants where they normally fail to appear. In this instance, as in the white axolotl (*v.i.*) local deficiencies of pigment-forming substances may be decisive in affecting the visible distribution of chromatophores.

PATHS OF MIGRATION

The pronounced power of migration of the chromatoblasts needs no further illustration. This is a property which they share with the other derivatives of the neural crest (see particularly Stone, 1922; Raven, 1931, 1936; Detwiler, 1937; and the review by Harrison, 1938). However, the exact paths of migration of those which ultimately reach the visceral organs and the parietal peritoneum is uncertain. Raven (1931, 1936) and Detwiler (1937) have shown that the trunk neural crest cells move beneath the epidermis and between the neural tube and the somites. Possibly the prospective pigment cells follow the latter course to reach the viscera. In teleosts Borcea (1909) noted that they spread out along both of these courses. The particular cytological studies necessary to decide this question are lacking in the amphibia. DuShane (1939) noted that their distribution in young larvae of the black axolotl suggested that the

> pigment cells moving out into the more fluid mesenchyme apply themselves to the denser structures and cling to them in further migration. The relationship of the pigment cells to the pronephric duct and tubules suggests that some prospective melanophores moving in contact with the surface of the somites or the basement membrane of the epidermis follow these structures medially to come into contact with the peritoneum where they spread both medially and laterally in close apposition to the surface. According to this view some reach the dorsal aorta by this means and follow its branches into the mesentery.

While this general distribution applies only to the one species, it may be suggested that the most vigorous migration takes place ventrolaterally, that is, beneath the epidermis. The observed relationship to the basement membranes of epithelia and other dense structures seems to be a general property of these cells. Numerous authors, mentioned earlier in this paper, have noted their distribution in relation to blood

vessels, the meninges of the central nervous system and the visceral and parietal peritoneum and pericardium.

THE DEPENDENCE OF PIGMENT CELLS ON EXTRINSIC FACTORS

Prior to the establishment of the theory of the neural crest origin of pigment cells, Harrison (1924, 1931) recorded the curious results of limb transplantation between various embryos of tailed amphibians (several species of *Amblystoma*, including the black and white varieties of axolotl (*A. mexicanum*). The transplanted limbs resembled those of the donor in form and size, but, except in combinations in which the white axolotl took part, they resembled the host limbs in pigmentation. DuShane (1935) found similar results in grafts of limbs and flank ectoderm and mesoderm between pigmented animals, provided the animals were at early or middle tail bud stages. In instances in which the donor embryos were in late tail bud stages, however, the grafted limbs developed donor, not host, pigmentation. DuShane suggested that in the younger embryos the potential pigment cells of the donor embryos had not reached the limb level at the time of its removal and transplantation. Consequently, host chromatoblasts would move into the limb and differentiate as pigment cells. The limb primordia of older embryos, according to this interpretation, would at the time of operation already contain prospective pigment cells. Hence, the grafted limbs developed donor pigmentation. Harrison (1935) reinterpreted his results in accordance with this explanation and published figures showing the pigmentation of a number of grafted limbs.

The above explanation did not account for the results of graft combinations involving the white axolotl. Harrison (1924, 1931, 1935) found that limbs of the white axolotl remained colorless when growing on a pigmented host and that the limbs of pigmented embryos became pigmented when transplanted to a white axolotl.

These relationships became understandable when the conditions under which pigment formation took place in the white axolotl were more closely investigated (DuShane, 1935). The white axolotl is not entirely devoid of pigment, but possesses scattered melanophores dorsally over the head and trunk. Melanophores do not ordinarily occur laterally below the level of the dorsal edge of the myotomes. When embryonic abdominal or flank ectoderm from a pigmented form (*Amblystoma punctatum*) was transplanted to the flank of the white axolotl numerous melanophores appeared beneath the grafted epidermis at the same time as the normal host melanophores developed on the head and dorsal parts of the trunk. The melanophores were closely packed beneath the graft and none extended beyond its limits. The graft melanophores resembled those of the host in size and form. Somewhat later xanthophores and epidermal melanophores appeared in the graft area. Since epidermis of the sort grafted had been shown by a variety of tests (explantation, transplantation) to have no ability to form melanophores or other pigment cells, it was clear that the melanophores were of host origin and were in some way dependent upon the overlying epidermis of the graft for their differentiation as pigment cells. These were termed "dependent" melanophores.

As a consequence of this necessity for the prospective melanophores of the flank to be closely associated with a pigmented tissue (in this instance epidermis) in order to develop pigment, the results with limbs are readily interpreted. In the case of a white limb grafted to a pigmented embryo, the prospective host melanophores migrate into the limb, but fail to form pigment due to local deficiencies in their tissue environment. On the other hand, a limb from a pigmented animal grafted to a white axolotl embryo receives the immigrant potential ("dependent") melanophores of the white axolotl which are activated to form pigment by some substance or substances in the tissue environment. Flank ectoderm and mesoderm of the white axolotl gave results similar to those with limbs, i.e. supported no host melanophores (Fig. 9) as found by DuShane (1934a).

That the ability to activate pigment formation is not confined to the ectoderm alone was shown by Harrison (1935). A limb composed of white axolotl ectoderm and *A. punctatum* mesoderm (a periclinal chimera) becomes moderately well pigmented. Harrison also confirmed the activity of the ectoderm in this regard by showing that limbs made up of white axolotl mesoderm and ectoderm from a pigmented embryo (*A. tigrinum*, *A. punctatum*) developed pigment. In both instances the chromatophores were not so numerous as in a normal limb of a pigmented embryo.

These experiments, together with those of DuShane, indicated that the tissues, both ectoderm and mesoderm, of pigmented embryos produce

some substance or substances necessary to pigment formation. Such substances appear to be lacking in the white axolotl at least in the region of the flank and limb.

These experiments led to the suggestion (DuShane, 1935) that possibly both the white axolotl and the pigmented embryos had prospective pigment cells of two sorts: one dependent on the tissue environment (ectoderm or mesoderm of a pigmented animal) for the supply of substances necessary to pigment formation; the other not dependent upon these tissues for the elaboration of pigment. This tentative hypothesis was introduced to account for the elaboration of pigment in the dorsally situated pigment cells of the white axolotl while those which reached the trunk failed to develop pigment. More recent experiments lead, however, to a different interpretation. Twitty (1936) found that the melanogenic effect of the ectoderm declined with time. Older ectoderm grafted dorsally to young embryos of *T. torosus* failed to stimulate melanin formation in the cells which normally form the dorsal bands. The pigment cells around the neural tube developed in the normal fashion. Among other possibilities Twitty suggested that the neural tube might share the melanogenic capacity of other ectodermal derivatives; or that the melanophores around the neural tube might be responsive to lower concentrations of substances from the skin than are the pigment cells of the dorsal bands; or finally, that these pigment cells might be autonomous as suggested by DuShane (1935).

DuShane (1939) grafted trunk neural folds between pigmented *A. punctatum*, black axolotl, and white axolotl embryos. The prospective melanophores of pigmented forms developing in the white axolotl behaved essentially like those of the host: they failed to develop pigment on the flanks and around the parietal and visceral peritoneum. This failure was interpreted as indicating deficiencies in the production of substances essential to pigment formation by the tissues, both ectodermal and mesodermal of the white axolotl. Conversely prospective pigment cells of the white axolotl grafted into the normal position in black axolotls became pigmented in all of these sites: in the flank and in the deeper visceral positions. In fact, such embrys are indistinguishable from normal black axolotls and the pigment cells of the two varieties may be regarded as equivalent in their ability to respond to the local tissue enviroment.

Further light was shed on the rôle of the mesoderm by grafting both neural folds and flank ectoderm on one side between the light and dark axolotls. Thus the grafted melanophores on the one side migrate between epidermis of graft origin and mesoderm of host derivation; on the other side they move between tissues of host origin. By comparing the results in reciprocal operations of this type, DuShane concluded that the ectoderm of black axolotl was somewhat more effective than the mesoderm in calling forth pigmentation in the associated melanophores. The corresponding tissues of the white axolotl produced this effect at a still lower level. In explanation of the pattern of the white axolotl, the concept of dependent and independent melanophores was abandoned in favor of a suggestion that

> on the flank the substance necessary for pigment production is not present in sufficient quantity to call forth the reaction. In the dorsal region, however, it is possible that the neural tube and dorsal fin mesenchyme together (both of ectodermal origin) together with the epidermis have a cumulative effect such that the substance is here produced in quantities slightly above the threshold for the reaction.

Under this interpretation all pigment cells would be regarded as dependent on extrinsic factors and the abundance of these factors is visualized as being highest in the region of the neural tube and dorsal fin and falling off to sub-threshold levels quite rapidly from dorsal to ventral.

DuShane further pointed out that

> While in these experiments the potential pigment cells of black and white axolotls appear to be practically equivalent, there is good reason to believe that in different species the chromatophores themselves have different potentialities. In the first heteroplastic transplantations of prospective pigment cells (DuShane, 1935), the donor pigment cells could be recognized by differences in intensity of color and size. In these combinations, the grafted pigment cells reacting with the same embryonic environment as the host cells, produced a greater or less amount of pigment. Obviously, the chromatophores are not, as in the case of the black and white axolotl, fully equivalent.

DeLanney (1941) extended these results by grafting ectoderm between a variety of species of *Triturus* and *Amblystoma*. Thus, he found that when pieces of ectoderm from other species were grafted to the flank of *T. torosus* embryos more than the usual number of host melanophores appeared beneath the graft. The capacity of

ectoderm to stimulate melanin formation in the dependent pigment cells increased in this order: *T. torosus*, *T. rivularis*, *T. similans*, *T. pyrrhogaster* (Twitty, 1936), *A. tigr. californiense*, *A. tigrinum*. DeLanney's experiments also indicate a difference in the reactivity of the potential melanophores of the different species. Thus the increase in number of melanophores under the stimulation of other ectoderms is greatest in *torosus*, less in *similans* and still less in *rivularis*. DeLanney interprets this in terms of the relative numbers of 'dependent' melanophores in the different species, there being many in *torosus*, and relatively few in the other species, capable of response to added ectoderm.

THEORETICAL CONSIDERATIONS

All of the results so far accumulated indicate that in those embryos which are sparsely pigmented (white axolotl, *Triturus torosus*) there is a large number of chromatoblasts (potential pigment cells) which normally fails to become pigmented. If their local environment is changed by transplanting them to more heavily pigmented embryos or by introducing ectoderm and mesoderm of pigmented forms, many of these potential melanophores develop pigment, i.e. the number of visible melanophores increases. In more highly pigmented embryos, it is a fair assumption that a larger percentage of the chromatoblasts normally becomes pigmented. Even in these instances, the chromatoblasts are unable to form pigment when transplanted to the flank of a pigment-poor form such as the white axolotl. The potential pigment cells of both lightly and heavily pigmented forms require some substances from the environment (ectoderm and mesoderm) in order to form pigment. It has been shown (DuShane, Harrison, Twitty, and, in particular, DeLanney) that the number of melanophores developed depends upon the melanogenic 'strength' of the surrounding tissues. By transplantation of ectoderm of various embryos to the flank of the white axolotl or *torosus*, it is possible to arrange them in a series with respect to their melanogenic power.

These results seem to be best interpreted by an expansion of previous hypotheses. The potential melanophores are thought of as a population with a normal variation of thresholds to melanogenic substances. This interpretation is an adaptation of the concept introduced by Hecht (1926) to account for the varying sensitivity thresholds of rods and cones and applied by Weiss (1941) to the explanation of the discharge of transplanted motor neurons. Figure A illustrates this concept. The normal curve (solid line) incloses total chromatoblast population. Those at the extreme left of the curve have a low threshold of reaction and consequently respond to minute concentrations of melanogenic substances. Moving toward the right the thresholds of the cells are increasingly higher and correspondingly higher concentrations of substances are necessary to stimulate pigment formation in these cells. The percentages of cells responding to any particular level of concentration of the melanogenic substances may be found by connecting the point of

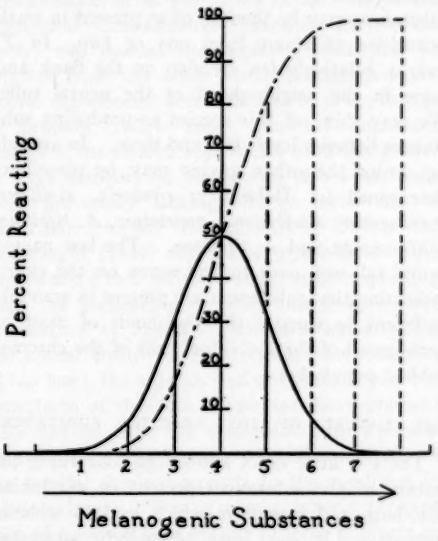

FIGURE A. (For explanation, see text.)

intersection of the various ordinates with the dotted curve (integral of the normal curve) to the vertical axis on which percentages are given. Thus, at a concentration at level 2, all of the melanophores in the area to the left of ordinate two in the normal curve would form pigment; the rest would remain colorless. Slightly more than two per cent of all chromatoblasts would respond. Similarly at level three, all melanophores to the left of the ordinate would respond (16 per cent). The remaining concentrations would exceed the thresholds of 50, 84, 98 and almost 100 per cent of the cells respectively.

There is reason to believe (see above) that the

melanophores of different species differ in reactivity. To represent such cases, the curve could be shifted to the left or right while the base line remained stationary.

While an exact quantitative comparison can not be made, it is instructive to consider the concentration of melanogenic substances present in some of the embryos which have been studied. The flank of the white axolotl is incapable of supporting melanin formation in the chromatoblasts; hence, the level of melanogenic substances would be below one in the chart. Dorsally around the neural tube and tail fin, a few melanophores develop: the substances are present just above the threshold of the most reactive cells. Here the substances may be thought of as present in small quantities at about level one or two. In *T. torosus*, relatively few develop on the flank and more in the neighborhood of the neural tube. We may think of this species as producing substances between levels two and three. In ascending order the other species may be placed as determined by DeLanney: *rivularis*, *similans*, *pyrrhogaster*, *Amblystoma punctatum*, *A. tigrinum californiense*, and *A. tigrinum*. The last named would fall well over toward seven on the chart, indicating that substances are present in amounts sufficient to surpass the thresholds of most or perhaps all of the individual cells of the chromatoblast population.

THE NATURE OF THE REACTIVE SUBSTANCES

There is little exact knowledge concerning the nature of the substances present in amphibian ectoderm and mesoderm which lead to melanin formation. It has been tentatively suggested that the substances might be enzymes or pigment precursors (DuShane, 1935, 1939). The enzyme hypothesis is tempting because of the success of the dopa reaction in mammals. Dopa (3.4: dioxyphenylalanin) is an intermediate oxidation product of tyrosine and appears to be a precursor of melanin pigment in mammals (see Bloch, 1917 and Raper, 1928). Dopa is oxidized by tyrosinase and by extracts of pigmented mammalian skin to melanin *in vitro*. The active extract has been termed dopa oxidase (Bloch, 1917). The location of dopa oxidase in the skin is tested by immersing frozen or formalin fixed sections of skin in dopa solution. Dopa-melanin is formed in cells which have the oxidase. Albino or white regions of spotted skin give no dopa reaction, while pigmented areas give the reaction both in the hair bulbs and basal layer. There is thus a general correlation between the presence of pigment and dopa oxidase, although this is not so perfectly correlated when the effects of particular genes on the oxidase are analyzed (review by Wright, 1942).

In amphibia enzymes capable of oxidizing dopa occur in the epidermis both in dark and yellow spots. That is, there is a reaction in all regions of the epidermis whether typical brown melanin pigment is normally present or not (Schmidt, 1919). This is not an insuperable objection to the significance of the reaction as Schmidt thought, since Wright finds that the dopa reaction in the hair follicles of guinea pigs appears to be largely a test for an enzyme involved in processes leading to the formation of yellow, while the reaction in the basal layer is a test for an enzyme leading to the formation of melanin. It is difficult to avoid ascribing some significance to the reaction in the ectoderm of amphibia, since it is weak in the white axolotl and progressively stronger in the black axolotl, in *Triturus similans* and *T. pyrrhogaster* (DuShane, 1936). The intensity of the dopa reaction is thus correlated with the abundance of pigmentation of the animal as a whole and also, so far as the comparison can be carried, increases in the same order as the melanogenic strengths of the ectoderms as determined by DeLanney (*v.s.*)

This evidence is far from conclusive and Twitty and Bodenstein (1939) and Twitty (1942) reject the enzyme hypothesis on the basis of experiments on melanin formation in tissue culture. They explanted prospective neural crest cells of several species of *Triturus* into a salt solution (Holtfreter's solution) and into boiled peritoneal fluid in hanging drop cultures. Melanophores differentiated in both cultures, but there were two important differences: there was a significant delay in pigmentation in Holtfreter's solution as compared to coelomic fluid; the cells in the Holtfreter's solution migrated much more extensively. Twitty and Bodenstein conclude that the coelomic fluid furnishes all substances necessary to pigment formation even after boiling which would presumably destroy any enzymes. The essential extrinsic substances are, according to this argument, not enzymatic. The formation of pigment in the cultures in salt solution is interpreted as due to the fact "that the neural tissue included in the explant may constitute a further source of essential factors, present in diffusible form." The more

extensive migration in the latter solution, they regard as probably related to the later onset of pigmentation, since migration appears to be confined to the period prior to melanin formation.

While the authors mention the possibility of the unlike physical characteristics of the media as being responsible for the differences in migration, they regard these as relatively unimportant. On the contrary, it seems more probable that slight differences in viscosity of the solutions and interface relations between the cells and the media might be the decisive factors in determining both the extent of migration and the intensity of pigmentation. If we assume that boiled coelomic fluid inhibits migration because of its physical properties, the cells would then remain near the mass of explanted neural tissue and hence be exposed to higher concentrations of melanogenic substances originating from the latter. Following the same thread of reasoning, those in salt solution would migrate more extensively and hence be farther on the average from the center of diffusion of melanogenic substances. The general result would be a lower mean production of melanin as Twitty and Bodenstein found. Further experiments are clearly required before any decision can be made.

It is of interest that not all cells in the latter type of explant become equally pigmented. This supports the idea discussed earlier of different reaction thresholds of cells exposed to identical concentrations of melanogenic substances.

RÔLE OF THE NUCLEUS IN PRODUCING MELANOGENIC SUBSTANCES

Although Dalton (1940, cited from Twitty, 1942a) has produced hybrid and merogonic embryos between several *Triturus* species, his experiments, while showing the dominant rôle of the nucleus in relation to pigment pattern, throw no light upon the rôle of the nucleus in relation to melanin production. Baltzer (1941) reports the only experiments which bear directly on this point. Baltzer fertilized denucleated black axolotl eggs with sperm of a white axolotl. One of the embryos was raised to the stage of pigment formation. Its pigmentation was entirely of the white axolotl type. Large pieces of ventral ectoderm were taken from gastrulae or neurulae of the same composition and transplanted to the flank of black and white axolotls. In all except one case of the fourteen available, the graft behaved entirely as would a graft from a normal white axolotl. It was entirely unrecognizable on the flank of the white hosts and, in all but one instance, it lay above a pigment-poor area on the flank of the black hosts. To summarize: the effects of black cytoplasm plus white nucleus are thus entirely due to nuclear activities and are autonomously developed.

METAMORPHIC CHANGES IN SKIN PIGMENT

Although the skin changes at metamorphosis have been the subject of numerous studies, exact studies of the pigmentary changes are wanting. Uhlenhuth (1917) described the gross changes in pigmentation in *A. punctatum* at metamorphosis. Epidermal melanophores disappear almost entirely, the dermal melanophores disappear or migrate from the areas where the xantholeucophores (lipophores) accumulate to form the orange or brilliant yellow spots. Another important change is the sudden appearance of melanophores in large numbers on the ventral skin where they were previously lacking. These latter are of particular interest. Experiments of Twitty and Bodenstein (1939) and those presented here in Figs. 4 and 6 to 8 inclusive show without question that the melanophores which make their first appearance at metamorphosis are derived from the neural crest. In Fig. 7a, the posterior part of the head, the anterior half of the trunk and the fore limbs of the host, *T. torosus*, have pigment cells derived from the transplanted *A. tigrinum* neural folds. The absence of melanophores over the ventral side corresponds to the condition in *tigrinum* larvae. During metamorphosis, pigment cells of *tigrinum* type appear in large numbers in this region with the result that a band of foreign pigment completely surrounds the anterior half of the host trunk. Spots rapidly develop in the graft skin as may be seen in Fig. 8a (cf. the control *T. torosus* in Fig. 8b). This indicates that for an indeterminate period before metamorphosis colorless prospective pigment cells of neural crest origin were situated in the ventral dermis. They become pigmented only during the high hormone levels developed at metamorphosis.

SPOTTING IN ADULTS

The light spots of adult tailed amphibia which develop during or after metamorphosis (Figs. 8a, 9) involve both the epidermis and dermis. In the European salamander, *Salamandra maculosa*,

Schmidt (1919) shows that the ordinary epidermal cells in dark areas contain melanin granules, while those of spots contain only yellow pigment. The dermis in dark regions of the skin is heavily populated by melanophores which stop sharply at spot areas. Yellow chromatophores alone occur in the dermis in spots. I can confirm that the same general relationships hold in the skin of *A. tigrinum* and *A. punctatum*. It is of particular interest that Woronzowa (1932) has been able to enlarge the spots in artificially metamorphosed axolotls by feeding thyroid and to reduce them by pituitary injections. By continued feeding of thyroid she found that the light spots expanded and fused with one another until, ultimately, they covered the entire body and no melanin pigment remained. On the other hand continued treatment with pituitary hormone led to the expansion of the melanic areas of the skin and ultimate abolition of the spots. These experiments indicate that spotting is controlled by a balance of hormones acting on locally different skin areas, and, further, that the particular expression of a chromatophore as a black or yellow pigment cell is dependent upon this total balance of factors.

It is worthwhile to reexamine the *T. torosus* with grafted *A. tigrinum* neural crest (Fig. 8a) with these relationships in mind. The host animal normally develops neither spots nor abdominal pigment. Yet the graft pigment cells in contact with host epidermis and dermis develop characteristic *A. tigrinum* spots as well as abundant abdominal melanophores. Similar results with other graft combinations have been reported earlier (DuShane, 1935).

It should be pointed out here that the origin of the dermis itself is uncertain. Raven (1931) thought that some of the neural crest cells in urodeles might contribute to the dermis and in 1936, he put this in more definite terms: that the dermis was derived from the neural crest. Holtfreter (1935a) and Detwiler (1938) support this opinion. The evidence is inconclusive and, except for Detwiler's work, confined to early stages during which the dermis is poorly differentiated. Detwiler has transplanted somites between *A. tigrinum* and *punctatum* and finds no difference in the dermis next to the transplanted and host somites. From this, he reasons that if the dermis were derived from somites, it should differ on the two sides of the larva. Since there is no detectable difference in the dermis, he concludes that it came from the neural crest, not the somites, despite the fact that he presents no evidence from normal embryos to show that the dermis of the one species differs from that of the other in any detectable way.

It is obvious from a consideration of these experimental and normal relationships that spotting in amphibia is a complex phenomenon, involving the entire skin, including the pigment cells.

SUMMARY

The history of the neural crest theory of pigment cell origin in vertebrates is traced. All modern experimental evidence is shown to support this theory which may be regarded as established beyond question for the amphibians. The dermal (larval melanophores, xanthophores, and guanophores, and adult melanophores and xantholeucophores) and visceral chromatophores are of neural crest origin. The origin of epidermal melanophores remains uncertain, although there are strong suggestions that these cells also come from the neural crest.

The pattern of distribution of the larval pigment cells depends upon: (1) The differential migration of the colorless cells to their definitive positions in embryos of different species. The extent of migration and final location depend largely upon intrinsic properties of the prospective melanophores, since they produce a normal pattern when transplanted to other species. (2) The final pattern is also an expression of the differential development of pigment in prospective melanophores. There is considerable evidence that chromatoblasts require some substance or substances from the surrounding tissues in order to synthesize pigment. These substances are present in different concentrations in various regions of a particular embryo and in embryos of different species.

The hypothesis is suggested that the prospective pigment cells have different thresholds of reaction to the melanogenic substances. This suggestion is in harmony with the results of transplantation and tissue culture experiments and should be tested by further experiments.

The nature of the melanogenic substance (or substances) present in the ectoderm and mesoderm of amphibia embryos is not known, although it has been suggested that it may be either an oxidase or a chromogen precursor.

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THE BIOGEOCHEMISTRY OF ALUMINUM AND OF CERTAIN RELATED ELEMENTS (*Continued*)

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THE OCCURRENCE AND ACCUMULATION OF ALUMINUM IN THE PTERIDOPHYTA AND BRYOPHYTA

FEW data exist that permit any satisfactory mean estimate for the Filicales. Church (1888b) was unable to confirm some of the older reports of the element in ferns and found but traces of aluminum in the British species that he examined. He expressly indicates that he examined *Aspidium Filix-mas* (L.) Sw. and *Athyrium Filix-femina* Roth. In the former Stoklasa records 0.51 per cent ash of the aerial parts to be aluminum. Most other ferns studied by Stoklasa gave higher figures; as some are common British species it is probable that Church examined others in Stoklasa's list. In *Ophioglossum vulgatum* L. Church found no aluminum; Stoklasa, 0.53 per cent in aerial, and five times that amount in terrestrial parts. Though Kratzmann gives qualitative indications of Al in *Ophioglossum*, Stoklasa's figures for reasons given previously are suspect. Church, however, did find Al in *Marsilea quadrifolia* L. (0.20 per cent ash or 0.033 per cent dry matter) and *Salvinia natans* L. (0.98 per cent ash, or 0.16 per cent dry matter). The latter plant he suspected was contaminated. Levy's sole analysis suggests a content comparable to that of the spermatophytes:

	Per cent Al, wet	*Per cent Al, dry*	*Per cent Al, ash*
Athyrium felix (sic. = presumably *filix-femina*) fronds.....	0.00672	0.0177	0.2087

Wherry (1932) finds 1.27 per cent Al in the ash of *Pteridium latiusculum* (Desv.) Maxon, growing on an acid woodland soil, 0.56 per cent when growing on serpentine-barrens soil from Pennsylvania. Kratzmann's qualitative microchemical studies appear to indicate a generally greater aluminum content than in the flowering plants, with a strong though not universal tendency for the element to become concentrated in the fertile parts of the plant. The value of these observations, as previously pointed out, is very questionable. Yoshii and Jimbo note aluminum detectible by their method in 13 out of 83 ferns studied, a slightly higher proportion than among the spermatophytes, for which their figure is admittedly high. They give no quantitative data, but it is clear from their results that *Plagiogyria matsumuraeana* Makino is a notable accumulator of the element, while in *P. adnata* Bedd, as in *Gleichenia linearis* Clarke, a marked but less intense concentration occurs. The other species giving a positive reaction presumably contain less than 2.5 per cent Al in the ash. Qualitative indications of aluminum accumulation by *Polypodium Feei* growing on an acid solfatara soil in Java are given by von Faber (1925).

Quantitative data exist indicating aluminum accumulation in two groups of ferns.

Dixon (1881) found in two Australian species of *Platycerium:*

	Per cent Al in ash	*Per cent Al in dry plant*
P. grande J. Sin. Clarence R....	4.35	0.375
P. alcicorne Desv. Clarence R...	5.54	0.250
P. alcicorne Newcastle.....	3.86	0.183

Platycerium grande is normally an epiphyte; *P. alcicorne* may grow on trees or on rocks. In the case of the former species, analyses of the wood and the bark of the tree on which the fern was growing showed no aluminum to be present, within the limits of sensitivity of the method used. The ash of the humus collecting between the fern and the tree contained 37.31 per cent insoluble silica and silicates, and 12.88 per cent Al_2O_3. At the same time a study was made of another epiphytic fern, *Asplenium nidus* L., growing in the same locality. In this species no aluminum was found,

and in the humus collecting at its base there was only a trace of Al_2O_3, 61.93 per cent of the ash of such humus being silica. Although the aluminum in *Platycerium* must ultimately be derived from air-borne dust and from rain, it clearly does not collect in the humus passively but only because it has first accumulated in the plant. Clear indications of selective uptake of other elements from such sources by *Tillandsia usneoides* has been given by Wherry and Buchanan (1926) and by Wherry and Capen (1928), who believe dissolved matter in rain water is of greater importance than is dust.

Aluminum also accumulates in some species of tree ferns (*Cyatheaceae*), but much work is needed to put the matter on a proper basis. Church (1888b) found in the ash of *Cyathea serra* A. from the West Indies a normal quantity of but 0.11 per cent of Al, though he believed this was of extraneous origin, but in a qualitative examination of a very small specimen of the caudex of *C. medullaris* Swartz from New Zealand he obtained an abundance of alumina, while in the ash of an undetermined New Zealand tree-fern, which may also well have been *C. medullaris*, he obtained 10.48 per cent Al. In the ash of the caudex of *Alsophila australis* Br. from Tasmania, Church also records "a very large quantity of alumina" and "more than mere traces" in that of *Dicksonia squarrosa* Sw. Yoshii and Jimbo find qualitatively recognizable amounts in *Cyathea spinulosa* Wall, *Alsophila bongardiana* Mett., and *A. latebrosa* Hook. They, therefore, consider the *Cyatheaceae* to be aluminum plants, but they place the species that they studied in their lowest qualitative category, probably corresponding to about 1 per cent Al in the ash, and so much poorer than the New Zealand species studied by Church. A complete quantitative study would be interesting.

Mariani (1888) found 0.41 per cent Al in the ash of *Equisetum maximum* Lam. (sub *E. telmateia*) which ash was remarkable for its extraordinarily high iron content. Church, however, found no aluminum in this species. Kratzmann gives qualitative data for *Equisetum* reporting moderate amounts of aluminum in some specimens, mainly in reproductive parts. Stoklasa (1922; *et al.* 1918a) found 1.08 per cent and 1.00 per cent in *Equisetum arvense* L. and *E. sylvaticum* L. respectively. The subterranean parts contained four or five times as much. These results are presumably not acceptable. Church found a doubtful trace of aluminum in *Psilotum triquetum*.

Among the Lycopodiales, the few analyses available for the *Selaginellaceae* indicate no accumulation in the ash:

Selaginella Kraussiana A. Br. (sub *Lycopodium denticulatum*)	1 per cent (Solms-Laubach, 1856; contaminated; *fide* Church, 1888b)
S. Martensii Spring var. *robusta*	0.14 per cent or 0.016 per cent dry matter (Church, 1874)
S. spinulosa A. Br.	0.0 per cent (Church, 1874)

Yoshii and Jimbo found that *Isoetes japonica* contained but 0.1 per cent Al in the ash and gave no alizarin reaction; as the ash content is very high, the aluminum content of the dry plant is 0.023 per cent. *I. asiatica* Makino, on the other hand, gave a marked alizarin reaction but was unfortunately not analyzed quantitatively.

In northwestern Europe, the traditional use of several species of the *Lycopodiaceae* in the dyeing of textiles was widespread. In some cases the plants themselves yielded a yellow dye, in others extracts were employed as mordants. Lightfoot (1777, p. 684) describes the use of *Urostachys Selago* in place of alum in the Hebridean island of Raasay, and elsewhere in Scotland. Schkuhr (1809, p. 164) indicates that *Lycopodium complanatum* was employed both as a source of mordant and of pigment in Russia. Francis (1855, p. 19), Sowerby and Johnson (1859, p. 31), and Hooker (1861, plate 49) briefly indicate that *L. clavatum* can be employed in a similar manner in mordanting. The first definite identification of aluminum in such plants was in the proximate analysis given by John for *L. complanatum* (1821a) or *L. clavatum* (1821b). John's detailed discussion (1821a) seemingly is not available in America. From the information given by Berzelius (1828) it appears that John examined *L. complanatum*. In a short abstract (1821b) the plant analyzed is referred to *L. clavatum*, and is said to have been used as a mordant in Norway. Subsequent studies by Salm-Horstmar (1847), Ritthausen (1851, 1853), Aderholdt (1852), Church (1874, 1875, 1888b), Langer (1889), Councler (1889), Stoklasa (1922; Stoklasa *et al.*, 1918), Yoshii and Jimbo (1932) and Hutchinson and Wollack (1943) have provided

a large number of analyses which throw light on the phenomenon.

The classical genus *Lycopodium* is now frequently divided into two genera, *Urostachys*, which branches dichotomously, and *Lycopodium* which is pseudomonopodial. In the lower sections of *Urostachys* the fertile leaves are not collected together to form a strobilus or cone. In both genera there is an evolutionary trend towards the production of a long stalk bearing a cone of fertile leaves, well separated from the green sterile leaves. Most species of *Urostachys* are tropical epiphytes, though among the lower members of the genus a number of geophytes are known. The following analyses are available for *Urostachys*, omitting two of those given by Hutchinson and Wollack, which are clearly grossly contaminated:

		Per cent Al in ash	*Per cent Al in acid sol. ash*	*Per cent Al in dry matter*	*Per cent Al in living plant*
Geophytic species					
U. Selago (L.) Hert.	North England (Church)	3.86	—	0.12	—
U. Selago (L.) Hert.	New England (Hutchinson and Wollack)	2.8–3.54*	3.1–6.40*	0.06–0.08*	0.03*
U. lucidulus (Michx.) Hert.	New England (Hutchinson and Wollack)	1.16–2.00	1.24–2.23	0.05–0.09	0.015–0.019
U. reflexus (Lam.)	Puerto Rico (Hutchinson and Wollack)	1.16	1.50	0.067	—
Epiphytic species					
U. verticillatus (L. fil.) Hert.	Puerto Rico (Hutchinson and Wollack)	1.36	1.55	0.074	—
U. Wilsoni (Underw. and Lloyd) Hert.	Puerto Rico (Hutchinson and Wollack)	0.83	0.87	0.04	—
U. dichotomus (Jacq.) Hert.	Puerto Rico (Hutchinson and Wollack)	2.42	2.85	0.27	—
U. taxifolius (Schwartz) Hert.	Puerto Rico (Hutchinson and Wollack)	0.32	0.33	0.0057	—
U. Billardieri (Spring) Hert.	? loc. (Church)	trace	—	—	—
U. Phlegmaria (L.) Hert.	? loc. (Church)	0.24	—	0.0098	—
U. Aqualupianus (Spring) Hert.	Puerto Rico (Hutchinson and Wollack)	0.90	0.94	0.042	—

* This plant, from Mt. Washington, is highly contaminated.

Some of the epiphytic species, notably *U. Billardieri*, *U. Phlegmaria* and *U. taxifolius* clearly contain no more aluminum than do normal terrestrial plants. To Church this seemed natural, but in view of the data relating to *Platycerium* already given, this low aluminum content is by no means inevitable in an epiphyte. For the other epiphytes, the evidence given by Hutchinson and Wollack suggests very slight accumulation.

Among geophytic species *U. Selago* certainly accumulates some aluminum, though so moderately that it must have been a miserable source of mordanting material for the Hebridean dyers. The other two species are hard to clean but the amounts of aluminum recorded appear to indicate some accumulation. On the whole the higher, epiphytic species seem to contain less of the element, and it is possible that there has been a progressive loss of aluminum during the evolution of the genus from some very moderate accumulator such as *U. Selago*.

The restricted genus *Lycopodium* is divided into a number of groups, subgroups, and sections. For these the following data are available, Stoklasa's few analyses being omitted as unsatisfactory.

		Per cent Al in ash	Per cent Al in acid sol. or silica-free ash	Per cent Al in dry matter	Per cent Al in living plant
Group EULYCOPODIUM					
Subgroup Clavatostachys					
Section Annotina					
L. annotinum L.	Germany (Councler)	9.6	—	—	—
"	Germany (Hutchinson and Wollack)	3.0	3.1	0.083	—
"	Eastern N. America (Hutchinson and Wollack)	0.96–3.52	0.99–4.17	0.02–0.11	0.02–0.04
" var. *acrifolium* Fernald	Eastern N. America (Hutchinson and Wollack)	1.92–3.44	2.13–4.11	0.03–0.11	—
" var. *pungens* Desv.	Eastern N. America (Hutchinson and Wollack)	1.43–2.98	1.51–4.38	0.03–0.07	—
Section Clavata					
L. clavatum L.	Europe (Ritthauser, Aderholdt, Church)	8.08–13.81	8.63–16.05	0.23–0.65	—
"	Eastern N. America (Hutchinson and Wollack)	2.52–12.65	3.63–13.40	0.11–0.39	0.04–0.18
" var. *Wallichianum* Spring	Assam (Hutchinson and Wollack)	5.4	8.7	0.26	—
L. contiguum Klotzsch.	Ecuador (Hutchinson and Wollack)	6.7	9.5	0.47	—
Section Obscura					
L. fastigatum R. Br.	Tasmania, N. Zealand (Hutchinson and Wollack)	3.7–6.7	4.2–7.6	0.10–0.27	—
L. spurium Willd.	Ecuador (Hutchinson and Wollack)	7.6	11.2	0.50	—
L. magellanicum Sw.	Fuegia (Hutchinson and Wollack)	9.8	11.5	0.42	—
L. obscurum L.	Eastern N. America (Hutchinson and Wollack)	11.00–12.45	12.80–14.61	0.31–0.40	0.14–0.21
" var. *dendroideum* Michx.	" "	10.59–14.69	12.95–17.88	0.33–0.54	0.13–0.32
Subgroup Complanatostachys					
Section Complanata					
L. nikoensis Franch. et Savat	Japan (Yoshii and Jimbo)	8.6	—	0.52	—
L. sabinaefolium Willd.	Eastern N. America (Hutchinson and Wollack)	13.55–21.55	15.17–23.22	0.62–1.44	—
" var. *sitchense* (Rupr.) Fernald	Eastern N. America (Hutchinson and Wollack)	15.0, 26.1	15.6, 27.1	0.44, 1.24	—
L. alpinum L.	England, N. America (Church, Hutchinson and Wollack)	18.8, 19.5	–20.4	0.69–0.80	—

		Per cent Al in ash	Per cent Al in acid sol. or silica-free ash	Per cent Al in dry matter	Per cent Al in living plant
L. complanatum L.	Europe, Japan (Salm-Horstmar, Ritthausen, Yoshii and Jimbo)	19.3–20.4	—	1.07 (Japan)	—
"	Eastern N. America (Hutchinson and Wollack)	16.6, 19.4	20.2, 23.2	1.01, 1.07	—
" var. *validum* Weatherby	Mexico (Hutchinson and Wollack)	25.0	27.4	1.73	—
" var. *tropicum* Spring.	S. America (Hutchinand Wollack)	18.7–25.8	23.9–32.0	1.47–2.65	—
L. flabelliforme (Fernald) Blanchard	Eastern N. America (Hutchinson and Wollack)	13.39–22.37	16.87–23.59	0.59–1.25	0.25–0.45
L. tristachya Pursh.	" "	19.60–25.90	22.22–31.36	0.89–1.83	0.51
	Europe (sub *L. Chamaecyparissus*; Aderholdt, Ritthausen)	20.7–30.2	31.8, 34.8*	1.8*	0.9*
Section Jussiaea					
L. scariosum Forst	New Zealand (Hutchinson and Wollack)	21.3	26.2	0.91	—
" var. *Gayanum* Bernh.	Valdivia, Chile (Hutchinson and Wollack)	23.0	25.8	1.36	—
Group INUNDATOSTACHYS					
Section Inundata					
L. inundatum L.	Eastern N. America (Hutchinson and Wollack)	8.35–8.6	11.3–13.2	0.39–0.48	0.16–0.22
" var. *Bigelovii* Tucherm.	" "	9.26	9.77	0.64	—
" var. *adpressum* Chapin	" "	2.27, 14.7	2.69, 17.70	0.13, 0.77	0.039
L. alopecuroides L.	N. Carolina (Hutchininson and Wollack)	9.20	13.95	0.60	0.14
Section Caroliniata					
L. carolinianum L.	N. Carolina (Hutchinson and Wollack)	10.70	15.0	0.98	0.15
Group CERNUOSTACHYS					
Section Densa					
L. densum Labill.	New Zealand (Hutchinson and Wollack)	11.7	13.6	0.34	—
Section Cernua					
L. cernum L.	? loc. (Church)	8.35	—	—	—
"	Puerto Rico (Hutchinson and Wollack)	12.50	17.32	0.71	—

* Aderholdt. The higher value is for plants gathered in November, the lower, in March; the data for wet and dry weight are not given separatelv.

		Per cent Al in ash	Per cent Al in acid sol. or silica-free ash	Per cent Al in dry matter	Per cent Al in living plant
Section Volubilia					
L. volubile Forst	New Zealand (Hutchinson and Wollack)	6.4	7.0	0.18	—
L. casuarinoides Spring	Oriental region (Hutchinson and Wollack)	19.0	20.5	0.85	—
Group LATERALISTACHYS					
Section Lateralia					
L. laterale R. Br.	Tasmania (Hutchinson and Wollack)	7.4	—	0.3	—

In addition to these records, von Faber (1925, 1927) found aluminum qualitatively in *L. cernuum* var. *vulcanicum*. Councler's analysis of *L. annotinum* is so different from the eight analyses of Hutchinson and Wollack that it is reasonably certain that it is based on a misidentified plant of *L. clavatum*. Within *Eulycopodium* there is a clear, though somewhat irregular, rise in aluminum content with increasing morphological complexity. Comparison is best made on a silica-free basis (Al in acid-soluble ash), as there is considerable variation in the amount of silica accumulated in the cell walls of these plants. The different species of a section in some cases differ significantly, *obscurum* being richer than the other members of section *Obscura*, *L. nikoense* lower than the other members of the group *Complanata*. Within the latter group, statistical tests show that while the tropical varieties of *L. complanatum* certainly accumulate more aluminum than does *L. flabelliforme*, when the latter is compared with *tristachya* the differences are of but moderate significance though comparison of the two species growing together indicates such differences are probably real. The relatively high content of *Inundatostachys*, which group, on morphological grounds, must be regarded as a specialized offshoot of a stock more primitive than *L. annotinum*, suggests that the capacity to accumulate the element has been developed more than once in the genus. On the whole this capacity is distributed throughout *Lycopodium* in the same way that any measurable, taxonomically significant, specialized character is distributed in a fairly large genus.

In the specimens of the section *Complanata* weighed in a fresh state by Hutchinson and Wollack, the aluminum content of the living plant lies, as has been indicated, between 0.3 and 0.5 per cent, so if it were evenly spread in solution through the liquid phase the latter would have a concentration between 0.1–0.2 gram-atoms per litre. Since the cell walls, which do not contain the element, form a large part of the volume in *L. tristachya*, the cell sap concentration in this species may well be as high as 0.3 gram-atoms per litre. Most of the other species of *Lycopodium* presumably have a concentration of about 0.05 gram-atoms per litre in the cells.

A relatively complete elementary analysis of *Lycopodium flabelliforme* and some determinations of certain elements in other species have been made by Hutchinson and Wollack. The species of the group *Eulycopodium* appear in general to be richer in manganese than do the other groups of *Lycopodium* or *Urostachys*. There is, however, no proportionality of manganese and aluminum contents, such as Stoklasa (1911) believed to occur in flowering plants. The analysis of *L. flabelliforme* indicates that apart from the high aluminum content, the amount of the other twenty-four elements determined (H, O, C, N, S, P, Si, K, Mg,Ca, Na, Cl, Mn, Fe, Ti, B, Ba, Sr, Cu, Zn, Ga, Pb, Ni, and Li) is essentially normal for calcifuge terrestrial herbaceous vegetation. The only suggestion of any abnormality, other than in aluminum content, is provided by the lead analyses which are rather high, but little truly comparable data from other species exists. The ratio of Al:Ga is clearly much higher than in the soil on which the plants were growing; in *Mitchella repens* from the same locality this is not the case. There is probably not an excessive accumulation of rare earths in *L. flabelliforme*. In several samples of the species analyzed the masses of potassium and aluminum are approximately equal, potassium being slightly in excess by weight in most, but not all, specimens. In atomic proportions, aluminum,

however, always appears to exceed potassium and is itself only surpassed by hydrogen, oxygen, carbon, and nitrogen. In the species accumulating massive amounts, as *L. flabelliforme* and *L. tristachya*, the cell contents of the entire plant appear to contain dissolved aluminum; in the lower members of the genus, as *L. annotinum*, microchemical investigation with aluminon generally indicates aluminum mainly in the pericycle. There is no evidence of aluminum impregnating cell walls in any species, as does silica in *L. tristachya* and *L. obscurum*, as well as in *L. cernuum* and several other tropical species of *Lycopodium* s. str.; where the cell wall surface comes in contact with aluminon and cell sap the mordanting action of the latter generally causes a purely superficial staining of the wall. The older workers concluded that aluminum acetate (John, 1821a, b), tartrate (Arosenius in Berzelius, 1845), or malate (Rithausen, 1851) are present. Church noted that a soluble salt can be extracted from *L. alpinum* with hot water. A complex organic ion may be present in the cell sap, the pH of which does not appear to be known. In view of the fact that the marked accumulations of aluminum occur only in certain sections of *Lycopodium* in the restricted sense, it is difficult to believe they have any fundamental metabolic function, though once having acquired the property of accumulating the element, irreversible adjustments to the chemistry of the plant may have become necessary to permit normal metabolism in an intracellular medium that frequently contains more than 0.1 gram-atom of aluminum per liter.

The data relating to the Bryophytes is meagre and for the most part unsatisfactory. Though Wiegmann (1847) recorded but 0.1 per cent Al in the ash of *Sphagnum palustre* L., the other early investigators, whose results are tabulated by Wolff (1871), obtained values between 1.6 per cent and 4.2 per cent Al in the ash of other members of the genus. These results appear to be confirmed not only by Stoklasa (*et al.* 1918a; *S. cymbifolium* Ehrh., 3.71 per cent, *S. acutifolium* Ehrh., 3.17 per cent, *S. lindbergii* Schimp., 3.32 per cent Al in ash), but by Hutchinson and Wollack (unpublished) who found 3.12 per cent Al in the ash of *S. lindbergii*. Wherever the sand content is recorded in the older work it is high and the same is also true of Hutchinson and Wollack's specimen. Monier-Williams (1935) finds 58 mg. per kilo, in *Sphagnum* sp. after careful washing; presumably this refers to the content of the fresh plant, and though higher than his few figures for seed plants, is not abnormally high. The iron content of all *Sphagna* analyzed is extraordinarily great. Since it is well known that the colloidal matter of peat and of dystrophic waters often contains great quantities of iron, presumably adsorbed on the dispersed humic material, it is not improbable that the high iron content of *Sphagnum* is also largely due to iron adsorbed on the lignin, perhaps primarily of the older, non-living cells of the plant. The relatively high aluminum contents of some *Sphagna*, if not due to contamination with solid matter, may therefore well be partly due to adsorbed aluminum derived from the acid water and soil in which the plants grow. Such superficially held material could hardly be regarded as part of the plant. Stoklasa analyzed a few other hygrophytic mosses and liver-worts, finding 1.66 per cent to 3.88 per cent of the ash to be aluminum. As with his other analyses, no great reliance can be placed on these figures.

Yoshii and Jimbo (1932) found aluminum to be qualitatively recognizable in five liver-worts out of eleven examined, and in ten mosses out of seventeen examined. No species gave their highest qualitative rating, but it seems likely that *Scapania spinosa* St. in the former group, and *Pogonatum contortum* (Menz.) Loesk, *P. inflexum* Lindh., and *Polytrichum sphaerothecium* Besch., would belong among the accumulator plants as understood in the present review. The sole quantitative analysis given by Yoshii and Jimbo relates to *Polytrichum juniperinum*, an obvious accumulator plant, containing 11.3 per cent Al in the ash or 0.55 per cent in the dry matter, a quantity about seven times as great as the iron content of the plant.

Von Faber (1927) states that epiphytic *Sphagnum* spp. growing on aluminum accumulators in Javanese solfatara soils also accumulate the element, and he records 24.4 per cent Al in the ash of *Leptodontium aggregatum* on *Eurya japonica* containing a like amount in the ash of the wood. Part of this accumulation, however, may be due to wind-borne mineral particles, and to dissolved matter in rain.

The only other species that has been investigated adequately is *Fontinalis antipyretica* L. Strohecker (1871) in a paper devoted to "phytochemical substitution," developed the view that in the composition of organisms, substitution of

one mineral constituent by another was comparable to the formation of a series of isomorphous crystals of varying composition. Thus it was supposed that CaO in the cell wall forms a complex with cellulose but that the calcium oxide can be replaced by MgO, MnO, FeO and even ZnO. A similar isomorphous substitution of phosphorus by arsenic was believed possible. Such a crystallographic interpretation of the organisms was doomed to failure, at the time that it was proposed, but now has a curiously prophetic tone. As an example, Strohecker used analyses from Wittstein's laboratory of *Fontinalis antipyretica* growing in the hard water of the River Isar and the soft water of the river Ohe. Not merely is the ash content of the moss higher in the hard than in the soft water, but it contains a far greater proportion of calcium in the former case, a greater proportion of iron, manganese and aluminum in the latter. It is conceivable that this is largely due to adsorption. The aluminum content of the ash was 0.856 per cent in the Isar, 4.91 per cent in that from the Ohe, corresponding to 0.086 per cent and 1.11 per cent Al in the dry plant. Unfortunately aluminum, being trivalent and so to Strohecker not capable of substitution for calcium, is not discussed, though the difference between the samples is greater in the case of aluminum than in those of iron or manganese. The general, if facultative, capacity of *Fontinalis antipyretica* to take up aluminum is indicated by an analysis of Church who found 1.48 per cent Al in the ash or 0.071 per cent Al in the dry matter of plants from the Thames and Severn Canal near Cirencester.

The aluminum content of the Thallophyta and Bacteria

Among the marine algae high results of the order of 0.5 per cent of the dry weight or 3 to 4 per cent of the ash were obtained by Stoklasa. Vincent (1924, *fide* Vinogradov, 1935b) gives a still higher figure for *Laminaria cloustonii*. These results are certainly erroneous. Lehmann found but 0.0284 per cent of the dry matter of *Fucus vesiculosus* L. and 0.0339 per cent of that of *F. crispus* to be aluminum. Meunier, moreover, obtained even lower values, from 40 mg. per kilo. (0.004 per cent) of the dry matter of *Fucus platycarpus* Thuret to 98 mg. per kilo. (0.0098 per cent) of that of *F. vesiculosus*. The mean of his determinations on five species is 0.0056 per cent of the dry matter. This would correspond to about 0.001 per cent of the wet weight or essentially the same amount as was found in the edible terrestrial plants studied by Winter and Bird, or by Levy. In view of the supposed richness of *Laminaria* in aluminum, it may be noted that Meunier found but 0.0058 per cent Al in the dry matter of *L. flexicaudis*. If Meunier's algae obtained all their aluminum from sea water the mean concentration factor would be about 20. Among fresh-water species there appears to be a single old analysis, by Petter (1862) who found 0.119 per cent Al in the ash or 0.0276 per cent in the dry matter of *Cladophora glomerata*. The available evidence therefore suggests that the algae as a whole are no richer in aluminum than are the normal flowering plants.

Although Bécamp (1871) noted considerable traces of aluminum in baker's yeast, Richards and Troutman (1940) who studied qualitatively the minor elements in the ash of yeast grown on five different media, found aluminum only in the culture from commercial yeast autolysate. It is evident from this work that the aluminum content of *Saccharomyces cerevisiae* Hansen is normally very low. The only modern determination for a geophytic fungus is Levy's analysis of *Psalliota campestris* (L.) which was the sole plant in which she was not able to detect the element. The old record of Kohlrausch (1867) of 0.25 per cent Al in the ash of the mushroom is presumably unreliable. A curious analysis of Nettlefold (1887) gives 8.3 per cent Al in the ash, 0.528 per cent Al in the dry matter, or 0.0441 per cent in the living *Bovista gigantea*. Since 72.18 per cent of the ash is said to be sodium phosphate, while calcium is practically absent and potassium not discussed, this record seems too improbable to merit much attention. Fritsch (1889) who was unable to detect aluminum in *Cantharellus cibarius* Fr., noted as of interest that *Pisolithus arenarius* Alb. et Schwein. (sub *Polysaccum pisocarpium*) contained 0.71 per cent in the ash or 0.276 per cent in the dry matter. The analyses of Kohlrausch and of Pizzi (1888, 1889) indicate from 0.42 to 1.93 per cent Al in the ash of the subterranean genera, *Tuber*, *Helvella*, and *Morchella*. Although Pizzi believed that his material was clean it is obvious that these plants give unusual opportunities for contamination.

Several investigators have examined fungi growing on various species of trees. Wolff (1854) found 1.66 per cent Al in the ash or 0.0199 per cent in the dry matter of a *Birkenschwamme* which

was certainly a member of the genus *Boletus*. Fritsch (1889), however, records but 0.01 per cent Al in the ash or 0.0007 per cent in the dry matter of *B. scaber* Bulliard, from an unrecorded habitat. Recently the matter has been studied by Nemeč (1936) in *Polyporus fomentarius* growing on *Carpinus betula* and on *Fagus sylvatica*.

	Per cent Al in ash
Carpinus wood and bark	2.60
P. fomentarius on *Carpinus*	12.70
Fagus wood	5.44
Fagus bark	0.39
P. fomentarius on *Fagus*	5.48

These results suggest aluminum accumulation in the fungus. The Al contents of the woods are, however, curiously high, and the higher record in the fungus refers to the lower record in the host. No indications of the technique employed are given. Further work is clearly needed on this very interesting case, as well as on the geophytic fungi, in which it may be suspected that the cases of aluminum accumulation are illusionary.

For lichens it is possible that the only reliable determination is for *Cetraria islandica* Ach. studied by Lehmann who found 29 mg. of aluminum per kilo. of dry lichen, an amount that is in the lower part of the range of the flowering plants. Gonnermann's (1919) record of 0.163 per cent of the dry matter is certainly excessive. Wittstein (1862) found 0.0184 per cent Al in the dry matter of the same species and both he and other contemporary investigators found comparable amounts, summarized by Wolff (1871), in other species. Three alleged cases of accumulation of aluminum have been recorded. Knop (1865) found 6.3 per cent Al in the so-called pure ash of *Lecanora esculenta* Eversm. (sub *Chlorangium Jussuffii*) but the dry plant contained 15.00 per cent sand and 16.01 per cent soluble or "pure" ash, so contamination by soluble minerals is possible. Knop (1868) later concluded that oxalic acid, derived by decomposition of lichen acids, caused a solution of inorganic mineral matter, permitting aluminum to enter this and other plants. Weigelt (1869) obtained similar results with *Parmelia scruposa* (Ach.) in which even more insoluble ash occurred. Coppola found 5.99 per cent Al in the ash of *Stereocaulon denudatum* Floerhe var. *vesuvianum* (Pers.) Laurer (sub *S. vesuvianum*), but again in spite of careful cleaning, much silica and iron were present. All these records must be regarded as suspect.

The sole record relating to the bacteria is that of Jackson (1901) who claimed that *Leptothrix* (sub *Crenothrix*) *ochracea* Kv. deposits more Al_2O_3 than any other single substance in the precipitates around its filaments, and considered it to be an aluminum rather than an iron organism. In the analysis that he gives, the precipitate formed by *L. ochracea* contains 33.3 per cent Al_2O_3 and 14.7 per cent Fe_2O_3, while his material of *Crenothrix polyspora* Cohn (sub *kuhniana*) had precipitated a sheath containing 31.6 per cent Fe_2O_3 and 5.7 per cent Al_2O_3. These relations are said to obtain whenever the organisms are compared. A third "species," *C. manganifera*, is said to deposit 33.9 per cent Mn_2O_3 in its sheath, while the other species are allegedly free of manganese. In all cases about one third of the material analyzed was organic matter. It has generally been considered that *L. ochracea* can obtain energy from the oxidation of both ferrous and manganous salts and this supposed facultative autotrophic nutrition (see Stephenson, 1939, for succinct review) naturally would give no support to the idea that aluminum plays any important part in its metabolism. Kalinenko (1940), however, finds that the belief that this bacterium obtains energy by the oxidation of ferrous iron is erroneous. The iron of the bacterial sheath is due to adsorption, and deposition continues after the death of the bacterial cells. If Kalinenko is correct, it is very probable that aluminum is deposited under some conditions, and it would be worthwhile to analyze natural specimens of precipitates in the sheath of *Leptothrix* by more modern methods than were available to Jackson.

As far as the available evidence permits any judgment, in neither the bacteria nor the thallophytes, have any cases of aluminum accumulation been adequately established and it is indeed not impossible that the mean aluminum content of the lower plants will actually prove to be less than that of the higher.

PHYSIOLOGICAL AND ECOLOGICAL ASPECTS OF ALUMINUM IN PLANTS

Distribution of aluminum in the plant body

Andreasch (1878) found a trace of aluminum in the roots of *Rosa remontana* but none in the other parts of the plant, while in *Dianthus caryophyllus* the root contained 1.36 per cent Al in the ash, the

stems a trace, the leaves none. Ricciardi likewise found more aluminum in the stems than in the leaves of mandarin orange trees. These results suggest a gradient in the distribution of the element. Berthelot and André (1895), on the basis of a few analyses of subterranean parts of one set of species, of aerial of another, concluded that in general aluminum enters the roots, but that little of the element is translocated to the aerial parts which they found very deficient in the element. While these results clearly do not go far to establish such a generalization, it is very probable that the relation postulated by Berthelot and André (1895) holds for a number of plants. The ease with which roots may be contaminated by soil must, however, be borne in mind. Stoklasa (1922; Stoklasa *et al.*, 1918a), as has been indicated above, concluded that while in xerophytes the aluminum content is uniformly low in both aerial and subterranean parts, the accumulation of aluminum which he believed characterizes the hygrophytes and hydrophytes is most marked when the roots are considered. As has been indicated above, it is difficult to know how much confidence may be placed in these results. The widespread existence of regular gradients in aluminum content is not confirmed by certain more recent studies.

True, Black, and Kelly (1918) found as much or more aluminum in spinach tops as in the roots (2.59–4.03 per cent of ash Al_2O_3 in normal, 3.49–4.41 per cent in blighted tops, 2.69, 2.37 per cent in normal roots, 2.51, 1.06 per cent in blighted roots). In a later paper (1919) they found that spinach fertilized in various ways showed consistently more aluminum per unit dry weight in tops (mean 0.31 per cent Al) than in roots (mean 0.16 per cent Al), though in percentage of the ash there was irregular variation in this respect and the mean was somewhat greater for roots (mean 1.67 per cent Al) than tops (1.50 per cent Al).

Latshaw and Miller (1924), whose analyses of *Zea* provide for many elements the most adequate data on distribution in the different organs of a single species, found accumulation in the roots but also to a lesser degree in the leaves. A comparable distribution is recorded by Shorland (1934) in Pampas grass (*Gynerium argentium*), and, with less detail, in other Gramineae and in red clover, in which the aerial parts were somewhat richer in aluminum than in the grasses examined. The data for *Zea* and *Gynerium* are as follows:

	Zea Per cent dry weight	*Gynerium* Per cent dry weight
Leaves	0.07	0.0048
Stem	0.013	0.0016
Grain or Plume	0.023	0.0053
Roots	0.98	0.014

In these plants, therefore, the root contains a considerable proportionate accumulation of aluminum, which in the case of *Zea* is also absolutely not inconsiderable, but as aluminum is concentrated in the leaves, the gradient implied by the early work of Andreasch and Ricciardi is not established.

Levy (1931) concluded that in parenchymatous edible roots the aluminum content is low; in unmodified roots of five cultivated plants she found more aluminum in the roots than in the aerial parts, in three species less. Green leaves contained more aluminum than etiolated leaves of the same plant, as is true of most other minor metallic constituents. Fleshy fruits she considered in general to be but moderately rich and seeds very poor in the element. Most of the analyses of plants grown in culture, in experiments on aluminum tolerance, reported below, indicate more aluminum in the roots than in the aerial parts, so that while such a distribution is not universal, it is clearly very widespread. Particularly good examples are given by Liebig, Vanselow, and Chapman (1942) for the lemon; these workers indicate a similar distribution for a number of other elements.

Of particular interest are the data derived from solfatara plants by von Faber (1925, 1927) in Java. Every species, when able to grow in such very acid soils, appears to accumulate more or less aluminum in the roots. In *Vaccinium varingiifolium* (Bl.) Miq., three species of *Rhododendron*, and *Gaultheria leucocarpa* Bl., little aluminum appears in the leaves; *Ficus diversifolia*, *Rapanea avenus*, *Myrica javanica*, and *Albizzia montana* gave stronger qualitative indications in the leaves, but again less than in the roots. In *Elaeocarpus punctatus*, *E. angustifolius*, *Melastoma setigerum*, *Symplocos spicata*, and *S. sessilifolia*, the whole plant appears to be very rich in the element. It would seem, therefore, that a series can be constructed, beginning with *Rhododendron javanicum*, in which the leaves are given the lowest qualitative rating, the roots the lowest but one, passing through the other *Rhododendron* spp., *Vaccinium*, and *Gaultheria*, in which the leaves still give the

lowest rating, while the roots are rich in aluminum, to the typical aluminum plants such as *Symplocos*. There is clearly a marked physiological difference in the ability of these different plants to exclude or absorb aluminum, and when it is absorbed, to immobilize the element in the roots or to translocate it throughout the plant. The fact that none of the *Ericaceae* appear to accumulate much aluminum in the leaves is particularly striking. A far more extended quantitative and physiological study would be of great interest, particularly in relation to the pH and the nature of the organic acids of the sap.

Possible biological functions

Neger's experiments on *Symplocos* have already been discussed. Though no more carefully controlled than those of other workers, they appear, from the nature of the plant studied, to indicate that the element plays a part in the normal growth of at least one of the noteworthy accumulators of aluminum. Very similar experiments by von Faber (1927) appear to indicate that *Vaccinium varingiifolium*, *V. lucidum* (Bl.) Miq., *Rhododendron retusum* (Bl.) Benn., and *Ficus diversifolia* require the element for normal growth, though in these species accumulation is confined to the roots. At least in the experiment on *F. diversifolia*, the control culture, without aluminum, was acidified, and the figures show a far poorer development than in the culture supplied with aluminum. By analogy we might expect to find that the other species of plants that accumulate large amounts of the element, even if only in the roots, actually require it. It has already been indicated that aluminum appears in the soil solution only at low pH values, and that some euryionic plants accumulate far more of the element on acid than on alkaline soils; it is therefore not impossible that the heterophyllous species of *Lycopodium* and the *Diapensiaceae*, which are primarily acid soil plants, are in part limited not only by hydrogen ion concentration but also by available aluminum. The converse situation in which soil acidity acts unfavorably by liberating aluminum is well established. It may be pointed out that any plants that had evolved, for an unknown reason, a mechanism for accumulating much aluminum, so that the cell sap, as is probable in *Symplocos*, *Shortia*, *Lycopodium* spp. contains 0.1–0.3 gram-atom per litre of aluminum in solution, might well have to make a number of adjustments in their whole metabolism. Such adjustments would probably throw the chemical mechanisms of the plant into confusion, when the aluminum is lacking. The situation may in fact be regarded as an evolutionary analogy to the case of the drug addict who suffers severe symptoms when deprived of a compound that plays no part in the metabolism of his fellows. Yet this analogy, applicable to any extreme adaptations, is, of course, imperfect, for the lowered social efficiency of the drug addict can have no counterpart in the life of *Lycopodium flabelliforme*, which, in spite of an extraordinary composition and immensely prolonged and ecologically most improbable life history, still can hold its own against the depredations of the vendors of Christmas wreaths.

Turning to species of normal aluminum content, various claims have been made as to the metabolic importance of the element. Among the lower plants Kratzmann (1914) found that *Aspergillus niger*, cultured with glycerol as the sole carbon source, grew better and produced more, though often later, fructifications in the presence of aluminum sulphate. The optimal concentration was 0.01 per cent; at 0.5 per cent no growth occurred. In the presence of peptone, the stimulating effect of Al disappeared. In view of the fact that iron was the only trace element added and that later work has not confirmed these experiments, we may conclude that impurities in the Al salts and in the peptone were responsible. Yoshii (1928) found no clear stimulation in a peptone medium, though 0.001 molar aluminum sulphate appeared to cause earlier sporulation. Levy found no effect, other than inhibition when massive doses (350 mg. per litre) were added. Steinberg (1938, 1939a, b.) has found no evidence of the need for aluminum, and attributes claims of the importance of the element to gallium contained as an impurity in the aluminum salts used. Steinberg (1939a) also finds that scandium is probably required when glycerol is the sole carbon source, but in Kratzmann's experiments a number of impurities was doubtless involved. In striking contrast to the results on *Aspergillus*, Yoshii found *Penicillium glaucum* to produce a twofold yield when 0.5 molar aluminum sulphate was present in the culture. Without hydrogen ion control no certain conclusions can be drawn from this experiment.

Young (1935) found that *Chlorella* sp. was stimulated by 0.02–0.2 mg. Al per litre, and *Crucigena* sp. by about the same amounts; in neither

case was the effect marked, but in an alga problematically designated as "No. 4" a considerable response to such concentrations was observed.

Kratzmann (1914) found that 0.01 per cent aluminum nitrate greatly favored the growth of prothalli of *Equisetum arvense* when cultured on nutrient salt agar. The experiments are admittedly not very exact. Traces of aluminum were probably present in the controls, while the experimental medium was probably more acid and certainly slightly richer in nitrate. The effects, however, were striking, the development occurring in the control cultures being very restricted. Although *Equisetum* sporophytes contain but small amounts of aluminum, unless Stoklasa's analyses of the subterranean parts be admissible, these experiments would probably repay further investigation.

Sprengel's (1828) claim that aluminum stimulated *Canna indica* has already been noted. Councler's (1883) finding of 0.28 per cent Al in the dry leaf of *Acer Negundo*, grown on soil, and none in the leaf of a plant from water culture, might be interpreted as a crude deficiency experiment, but was reported without comment. Modern studies on the higher plants appear to have been initiated by Yamano (1905) who found that flax and barley, grown in sand cultures, were improved by the substitution of 0.2–2.0 grams per kilo. of Al $(SO_4)_2NH_4.12\ H_2O$, for an equivalent mixture of sodium acid sulphate and ammonium sulphate. The most striking effect was an increase in the yield of barley grain. As in most of the other early work on aluminum, both as a stimulant and a poison, the lack of adequate control of the acidity makes interpretation difficult. Some curious experiments of Micheels and De Heen (1905a, b) suggested that metallic aluminum immersed in culture fluid might be stimulatory to the roots of wheat seedlings. House and Gies (1906) found that aluminum salts in concentrations from m/2097152 to m/65536 tended to stimulate *Lupinus* seedlings; more concentrated solutions were inhibitory.

Stoklasa (1911) introduced the important method of alternating nutrient solutions containing phosphate with solutions containing aluminum, a technique much used by later workers but apparently abandoned by its original sponsor in later works. Stoklasa found that 13.6 mg. per litre (i.e. 0.5 mg. atoms) stimulated development in four cereals and a species of *Polygonum*. Doubling the amount of aluminum produced less stimulation, but in all cases a greater yield than in the controls. Varvaro (1912) claimed, on meagre evidence, that 5 g. of aluminum as oxide in 1 kilo. of sand stimulated germination of *Zea*. Bertrand and Agulhon (1912) found 2 mg. Al per kilo. of soil stimulatory to barley and to radishes, while Boullanger (1912), growing various vegetables in soil culture, believed aluminum to stimulate lettuce, chickory, onion, carrot, celery and potatoes. The significance of experiments, in which minute quantities of aluminum are added to soil, is clearly problematic. Pfeiffer and Blanck (1914) found vague indications of stimulation of oats when 0.062 g. Al as sulphate were added to 17 kilos. of nutrient sand, both cultures receiving manganese as well as the ordinary nutrient elements. Clear inhibition occurred with the addition of 0.5 g. Al. No certain effect of aluminum on the percentage of nutrients contained in the plant was observed. The transpiration per unit dry weight was decreased by both stimulatory and inhibitory concentrations of aluminum, and by stimulatory concentrations of manganese. Kratzmann (1914) found that while 0.005 per cent Al inhibited the growth of *Zea mays*, *Vicia faber*, *Lens esculente*, and *Helianthus annuus*, a concentration of 0.0001 per cent was somewhat stimulating. Mazé (1915, 1919), using a complex culture solution prepared from specially purified chemicals, found that omission of aluminum caused inhibition of the growth of maize. The solution contained, among other elements, arsenic, but no experiments were performed in which both aluminum and arsenic were omitted, although omission of arsenic alone improved the yield. The aluminum present may have precipitated some arsenic so that under the experimental conditions no clearcut results can be expected. Other experiments using fluorine and aluminum are also somewhat equivocal. Stoklasa (1918b) claimed that *Juncus effusus* and *Glyceria aquatica* died without aluminum and that other hydrophytes grew poorly. He again maintained that *Hordeum*, *Triticum*, and *Avena* were stimulated by the addition of the element, but that certain xerophytes were unaffected, provided the amount added was less than 1 mg. atom per litre, above which concentration injury was observed. Stoklasa believed that aluminum ions specifically antagonized manganese and iron, and that the rôle of aluminum in the root was to prevent injury by the iron and manganese taken up by that organ from the soil. As is indicated below, the choice

of iron and manganese as the elements involved was unfortunate. He also believed, though without any impressive evidence, that aluminum has catalytic functions; as will be later pointed out, one case in which aluminum acts as a cofactor in an enzyme system is now known in animals. Sommer (1926) points out that since, in the experiments just discussed, Stoklasa's cultures were regularly aerated in the presence of a large amount of calcium phosphate, the aluminum added cannot have remained in solution; moreover, the lowest amount added to the cultures of wheat, barley and oats, in both these and also in his earlier experiments, would certainly have been toxic had it not been so removed. Like the rest of Stoklasa's work, these experiments therefore remain problematical.

Sommer grew various plants from seedlings in solution cultures, using both aluminum-free and unpurified salts. A preliminary experiment with wheat indicated 2 mg. per litre aluminum was excessive and caused injury. With peas a slight increase in seed yield was obtained when 0.5 mg. per litre Al was added to the purified medium, and a further slight increase when 1 mg. per litre of unpurified salts were used. With millet very striking results were obtained when aluminum-free cultures were compared with those in solutions containing 1 mg. per litre. This is particularly shown in the production of seed, which was increased over 20 times by the addition of the element. Sommer's work, though requiring careful repetition, certainly provides *prima facie* evidence that aluminum is essential to the maturation of millet seed. It is worth noting that both Yoshida (1887) and Myers and Voegtlin (1914) found millet to contain rather more Al than other grains, though the absolute amounts given by these investigators are not concordant. Some of Sommer's critical experiments were largely vitiated by fungus infections, and at the time that the work was done, iron and manganese were the only minor elements that were certainly deemed essential in making up nutrient solutions. It is admitted that bean seedlings, also used in some of these experiments, suffered from boron deficiency and it is not impossible that deficiencies other than that of aluminum interfered with the experiments with other species. McLean and Gilbert (1928) obtained results that were interpreted as indicating that 3.4–13.6 mg. Al per litre may stimulate rye, alfalfa, buckwheat, oats, onion, and red top. Their data are, however, too irregular to justify any such conclusion. Scharrer and Schropp (1936) found that the addition of from 0.001–1 mg. Al as sulphate to 800 grams of unfertilized sand stimulated the growth of seedlings of corn and perhaps oats; in the lower part of the range stimulation was irregular. Higher concentrations were toxic. Barley, wheat, and rye were injured by all concentrations studied, the first most, the last least. The stimulation observed in sand culture without nutrients may have been due to phosphorus conservation in the roots, as is believed to have occurred in the next series of experiments, or to inhibition of the toxic effects of excess copper, as in the work of Liebig, Vanselow, and Chapman (1942). No such stimulation of corn was observed in nutrient solution cultures in which some inhibition at extraordinarily low concentrations is recorded. In general these experiments are not very convincing. Young (1935) claimed addition of ten parts per million of aluminum to soil cultures of Timothy (*Phleum pratense* L.) produced an increased yield, but the presentation of his results leaves much to be desired. Haas (1936) who earlier (Haas and Reed, 1927) had found a beneficial effect of aluminum and of a number of other elements, reports that when citrus cuttings are grown in solution culture lacking phosphate, the presence of aluminum greatly improves the health and growth of roots, though the tops may be inhibited. It is reasonable to suppose, as Haas very tentatively suggests, that phosphate derived from the cutting is precipitated by the aluminum in or on the root, where it can be used by the latter but can not be translocated to the top, or dissipated into the culture solution. It is, however, doubtful whether aluminum would ever play such a part as a regulator of phosphorus metabolism in the field, under either natural or cultural conditions. Certain experiments of Yoshii (1928), indicating increased growth of cuttings of various plants when supplied with aluminum, may have a comparable explanation, though in these cases varation of hydrogen ion concentration is also likely to have been involved.

Lipman (1938) studied *Helianthus* and *Zea*, adding 1 mg. per litre Al. The effect on the sunflower was negligible; on corn more striking results were obtained, the mean dry weight of the whole plant being increased by about one fifth, while that of the ears of corn was doubled. There was considerable variation in both treated and untreated series,

but at least in the case of the ears, the increment appears significant. The work of Latshaw and Miller, already indicated, showed slightly more aluminum in the grain than in the stem.

Two recent investigations in which groups of trace elements were studied together indicate that aluminum is possibly involved in the metabolism of the peppermint, *Mentha piperita* L. (Bode, 1940) and the Myrobalan plum (Hoagland, 1941). In the case of the former plant evidence of ionic antagonism between aluminum and some other element was obtained, but the evidence of the essentiality of aluminum is unconvincing. In Hoagland's experiments, addition to the nutrient solution of twenty elements, of which Al is perhaps the most likely to be of significance, appeared to be beneficial in certain cases.

Aluminum and copper toxicity

The most recent contribution, which is also the most interesting, is that of Liebig, Vanselow, and Chapman (1942), who studied the effect of aluminum in nutrient solutions used for the culture of Valencia orange and of lemon cuttings. The nutrient solution which included all the trace elements, save copper, deemed to be essential, contained 0.005 to 0.01 p.p.m., i.e. about 5–10 γ Al per kilo. From this a considerable accumulation of aluminum occurred, as is indicated in the table below. Addition of 0.1 mg. of aluminum raised the aluminum content of the "root-bark" and finer roots, but not of the stem and leaves, a phenomenon noted in other experiments to be discussed below. Addition of 0.1 mg. of copper without aluminum had a markedly toxic effect on the citrus cuttings, but this was entirely eliminated by addition of 0.5 mg. aluminum.

Treatment	*Aluminum p.p.m. dry matter of*					*Copper p.p.m. dry matter of*					*Remarks*
	Leaf	Stem	Root wood	Root bark	Finer roots	Leaf	Stem	Root wood	Root bark	Finer roots	
Nutrient solution alone.....	28.0	5.6	4.5	92.0	280	5.5	5.6	4.6	18.0	95.0	Healthy
Nutrient solution + 0.1 p.p.m. Al.....	10.0	7.0	5.2	340	970	9.0	5.5	5.8	20.0	78.0	Healthy
Nutrient solution + 0.1 p.p.m. Cu.....	25.0	8.6	3.5	110	350	5.2	8.0	5.0	39.0	890	Symptoms of copper poisoning
Nutrient solution + 0.1 p.p.m. Cu and 0.5 p.p.m. Al.....	22.0	5.6	9.2	700	1000	7.4	7.0	9.2	22.0	710	Healthy

Analytical data are also given for many other trace elements. Evidence was obtained that the aluminum did not precipitate copper in the medium. It will be observed that the copper in general is distributed like the aluminum, and that the latter does not prevent entry of copper into the plant. It is supposed that the antagonism is primarily exercised in the fine roots. Szücs (1912) had previously obtained evidence of antagonism between aluminum and copper in studies of the geotropism of the hypocotyl of *Cucurbita Pepo*. It is curious that Stoklasa should have postulated a very similar antagonistic mechanism acting in the root, but involving the wrong elements, namely iron and manganese. Liebig, Vanselow, and Chapman suggest that in the absence of excess copper, the inhibition due to aluminum, shortly to be discussed, is due to copper deficiency. It is perhaps conceivable that the rôle of aluminum as a cofactor in the succinoxidase system, to be discussed later, is involved here, as this system is inhibited by copper. However, such an interpretation would involve additional hypotheses as to the existence of a considerable concentration of inactive enzyme, in the presence of aluminum in biologically large concentration, so that it probably cannot be seriously entertained at present.

Indirect effects beneficial to certain plants

In addition to these experiments, the work of Coville (1923, 1927) on the beneficial effects of the application of aluminum sulphate to sickly plants of *Rhododendron*, *Franklinia*, *Vaccinium*, etc. must be mentioned. These experiments, which form the basis of a standard and successful modern horticultural practice, are not necessarily to be interpreted as a demonstration of a direct effect of the element, though von Faber's work perhaps indicates a true physiological rôle for the element in *Vaccinium*. Coville supposes that the effect of the addition of the aluminum is to cause leaching of calcium as calcium sulphate, and a fall in pH, producing conditions suitable for calcifuge acid-soil

plants. Comparable cases are described in which the "damping-off" (Hartley, 1928; Wiant, 1929; Doran, 1931) of coniferous and other seedlings can be prevented by application of aluminum sulphate. Such diseased conditions are caused by fungal infections; working with *Pithium* and *Rhizoctonia*, two of the fungi involved, Jackson (1940) has shown that the application of aluminum is effective only by virtue of the increase in acidity produced. These cases exemplify the environmental, as opposed to the internal or physiological importance of the element.

Summary of supposed metabolic rôle of aluminum in plants

Apart from such indirect effects, the present position with regard to the metabolic rôle of aluminum in plants may be summarized, therefore, as follows. The element is apparently required for normal growth by *Symplocos*, the most marked of all the plant accumulators and probably for certain other species containing much of the element. Among plants of ordinary composition, there is some evidence that aluminum plays a part in the setting of seed in millet, and perhaps in corn. There is clear evidence that an antagonism between aluminum and copper plays an important rôle in the detoxication of excess of the latter element. Under artificial conditions of phosphorus starvation, aluminum may aid in the conservation of that element. There are persistent hints of some rôle in water metabolism, discussed again below, but never properly substantiated. On the whole it is probable that part of any normal metabolic activity that the element may have, takes place in the roots, but again the evidence is inadequate. Steinberg has suggested that some of the stimulatory effects attributed to aluminum may be really due to gallium contained as an impurity in the added aluminum salts. Steinberg's own work (1938, 1939a, b, 1941) on *Aspergillus* and *Lemna* indicates that if aluminum is required by these plants, it is in quantities too small either to detect or remove; in view of the accumulation of aluminum by citrus roots from very dilute solutions and of the rôle of aluminum in at least one enzyme system of very wide occurrence, namely the succinoxidase system of animal tissues, this possibility cannot be dismissed.

Effect of aluminum ions on cells

Most of the specific investigations are old, preceding the introduction of pH control. In accordance with the general purpose of the review, only work that has some bearing on the normal function and ecology of the element will be considered. Rothert (1906) found parenchymatous roots absorb aluminum strongly; Meurer (1909) further found this to be true of carrot and beet slices, either alive or killed with chloroform. He considered that the aluminum combined with the cell wall or possibly with pectic material of the middle lamella. Fluri (1908) found that cells become less subject to plasmolysis after treatment with aluminum and that starch disappeared from the cells of certain water plants, a phenomenon partly but not completely confirmed by Kratzmann (1914). Fluri supposed that enzymatic hydrolysis was increased, photosynthesis inhibited and permeability increased, allowing loss of sugar. Neither of the first two contentions is adequately established, and the belief that the permeability increases, is based on a misinterpretation of the plasmolysis experiments. Szücs (1913) showed by centrifuging such cells that the cytoplasm of cells treated with aluminum salts frequently becomes reversibly gelated. The experiments of Szücs, and of Mann (1924), moreover, indicate that permeability to cationic dyes is decreased by aluminum salts. All of these effects are probably also produced by other trivalent cations such as Y^{+++} and La^{+++}. Working with animal cells, mainly Echinoderm eggs, Heilbrunn (1928) found the initial effect of aluminum and cerium ions to be a decrease in viscosity, which he attributed to adsorption of the positively charged ions causing an increased charge on the colloidal particles of protoplasm and so an increase in dispersion. Most of the work on animal cells is concerned with the use of trivalent cations as tools in physiological research and is outside the scope of the present review.

Aluminum toxicity and aluminum as an ecological factor

Although it appears from the earlier work of Coupin (1901), House and Gies (1906), Rothert (1906), Kratzmann (1914), Miyake (1916), and Stoklasa (1911, *et al.* 1918b) that aluminum in sufficient quantity is toxic to plants, the experiments of these authors were done without control of hydrogen ion concentration, or with single salt solutions which may be deleterious irrespective of the nature of the salts employed. The first workers seriously to emphasize the possible importance of aluminum as an environmental factor were Ruprecht and

Morse (1915, 1917; Ruprecht, 1915) and Hartwell and Pember (1918), though Abbott, Conner, and Smalley (1913) had approached the matter from a comparable viewpoint, but concluded that the acid in equilibrium with the aluminum was the important factor. Ruprecht and Morse were concerned primarily with the deleterious effects of excessive fertilization with ammonium sulphate, though the result of this provides a model of an important natural condition. Hartwell and Pember were led to their investigation by the observation that whereas rye and barley grow equally well in solution cultures to which a given quantity of acid had been added, in agricultural practice barley is clearly inhibited on certain acid soils on which rye can be grown. This observation provides the basis for regarding some factor other than the hydrogen ion as an important ecological variable in acid soils. The inhibiting agent was found to be a dialysable inorganic substance, and culture experiments indicated that similar inhibition could be obtained with aluminum. Although control cultures containing acid were used, there is no proof that the pH of these remained as low as in the aluminum cultures throughout the experiment. Hartwell and Pember further investigated the observation made in agricultural practice that the growth of barley on acid soils was improved by treatment not merely with lime but also with phosphate. They confirmed this in soil cultures, and concluded that since both neutralization and addition of phosphate will tend to precipitate the aluminum, the effects were to be attributed to such precipitation. Conner and Sears (1922), Burgess and Pember (1923), Barnette (1923), Blair and Prince (1923), and Schuckenberg (1924), using different techniques, came to the same conclusion that the aluminum rather than the hydrogen ion was the most important limiting factor in acid soils. Line (1926) has criticized this work in a comprehensive review of the earlier contributions. He draws attention to work by Denison indicating that Mirasol had greatly overestimated the soluble aluminum present in soils, and concludes that even in acid soil the amount is very small. Line concluded that in no case had adequate pH control been used in the experimental studies. His own experiments on barley growing in soil cultures led him to conclude that the hydrogen rather than the aluminum ion is the effective agent in all cases; the only one of these experiments which is reported in full indicates, however, that though the addition of aluminum produced no greater effect on the plant than the addition of enough sulphuric acid to obtain the same pH, the concentration of the soluble aluminum was essentially identical whether the element was added or not, and was highest in the most acid cultures. The summary of the data as reported provides no possibility of distinguishing the effects of H^+ and Al^{+++}.

The earlier work as a whole is now of little interest. It called attention to a possible analysis of an important agricultural problem, and in providing a practical antidote in the form of calcium and phosphate, added somewhat to the evidence that the analysis is correct. A full review is given in Line's paper; his criticisms have now largely been met by later workers, and if the problem appears more complex than formerly, its ecological significance is much enhanced.

McLean and Gilbert (1927), using a technique derived by Stoklasa (1911) in which plants were exposed alternately to a nutrient solution containing phosphates, and to one containing aluminum, the two substances being incompatible, concluded that crop plants could be classified into

> Sensitive (depressed by 2 p.p.m. aluminum added): lettuce, beet, timothy, barley.
> Intermediate (depressed by 7 p.p.m. Al added): radish, sorghum, cabbage, oats, rye.
> Resistant (depressed by 14 p.p.m., i.e. about 0.5 mg. atom): corn, turnips, red top.

In a second paper (1928) these authors found aluminum citrate, which is soluble in less acid solutions than those used in previous experiments, was toxic at pH 6, and that colloidal aluminum hydroxide in contact with barley roots, is poisonous, unless much phosphate is present. Gilbert and Pember (1931), also using the technique of alternating solutions, found lettuce seedlings relatively insensitive to the pH of the culture media, but to be depressed about 30 per cent by 28 mg. per litre Al as sulphate. This depression seems low compared with that of the previous workers, but provides some evidence of the specific effects of aluminum, though the pH control was not very rigid. The average pH values in the cultures varied considerably, being from below 4.0 to above 6.0 in some species in each category. In the case of the higher values, some Al must have been precipitated. They also studied the growth of barley in soils containing varying amounts of "active" aluminum, extractable with dilute acetic acid, between pH 5.04 and 5.83, and concluded that such aluminum is depressive.

Skeen (1929) found *Lupinus albus* much more resistant to both Al and Fe in single salt solutions than is *Phaseolus vulgaris*. Iron was much more toxic than aluminum and caused loss of root turgor; this did not occur in aluminum solutions which produced scaly and brittle radicles which were bent and greatly distorted. With 0.5 and 1.0 p.p.m. Al a great stimulation of the elongation of the radicle was observed, with the addition of calcium, growth was almost normal. Skeen thought that *Lupinus* might possibly be benefited by the presence of aluminum. It is noteworthy that increase in height of young rice plants accompanied by decrease in dry weight has been recorded as caused by aluminum (Villa, 1929), so that elongation may be produced at concentrations that are not, in general, favorable.

Ligon and Pierre (1932) studied barley, sorghum and maize, namely one species from each group of the three established by McLean and Gilbert. They found, however, that in every case some damage was done at a concentration of 1 part per million Al. At low concentrations, barley was the most seriously injured, sorghum the least; at higher concentrations, sorghum was the most injured, maize the least. Ligon and Pierre suppose that the discrepancy between these results and those of McLean and Gilbert is due to the fact that the latter authors overcrowded their plants and did not control the pH. They are also known to have used well water, which may have contained enough silicate to form a less toxic complex with the added Al. Ligon and Pierre's work, however, may be criticized on the grounds that some silicate was present in the NaOH used in adjusting the pH. Trenel and Alten (1934) found that 4 mg. per litre was toxic to maize, tending to confirm the low value set by Ligon and Pierre. There seems no doubt that at high Al concentrations, maize is less sensitive than barley, though the reduction of pH from 6.0 to 4.5 in the absence of aluminum reduces the yield of corn almost 50 per cent while hardly affecting that of barley. Thus in passing from a solution at pH 6.0 free from Al to one at pH 4.5 containing a typical quantity of 4.6 mg. per litre, the growth of maize is reduced by 79 per cent, of barley by 72 per cent, but in the case of the former plant almost half the inhibition is due to the low pH, in the latter all to the aluminum.

Scharrer and Schropp (1936) again found maize less sensitive than the other cereals; in solution culture, however, they give figures that, if taken at their face value, indicate some inhibition of maize roots at incredibly small concentrations, of the order of 10^{-10} mg. (presumably per culture vessel). The inhibition, however, is about 15–30 per cent of the control in the entire range of concentrations until 10 mg. are added, when the root is inhibited about 50 per cent. The smaller inhibitions in dilute solution can hardly be taken seriously.

In a later paper Gilbert and Pember (1935) studied certain wild plants, using the same technique as McLean and Gilbert, but different categories; they conclude that *Cerastrium vulgatum*, *Taraxacum officiale*, *Poa pratensis*, *Stelleria media*, and *Prunella vulgaris* are depressed at least 20 per cent by Al concentrations between 2 and 8 p.p.m., *Leontodon autumnalis* and *Digitaria humifusa* by concentrations between 12 and 32 p.p.m., *Agrostis tenuis*, *A. alba*, *Digitaria sanguinalis* by more than 32 p.p.m. Control experiments, not fully reported, conducted at the same pH using sulphuric acid, appear to justify their conclusion that the effect is due to aluminum. It is difficult to evaluate the significance of the absolute quantities, but the relative differences are doubtless ecologically significant, as the authors believe, in regulating competition between certain grasses and dicotyledonous weeds in favor of the former on acid soil. Certain results already discussed, such as those of Bergstrand on *Rubus arcticus* and of von Faber on solfatara plants, to which may be added Aarnio's (1922) record of a sparse growth of *Spergularia salina* on alum soils in Finland, indicate that certain plants have very great tolerances to aluminum.

The experiments hitherto discussed were conducted with synthetic media, but a number of authors have studied the effect of the variation of pH and aluminum in displaced soil solution, on the development of the plants grown in the soil. Such experiments, which are comparable to conditions in nature, indicate considerable variation in the toxicity of Al under different conditions. The most significant work is that of Mattson and Hester (1933). They studied the growth of wheat seedlings in electrodialysed soils adjusted to various pH; in one soil, however, the injury observed was primarily due to manganese. In the two soils primarily giving rise to aluminum injury, the threshold concentration for inhibition lay between 1 and 2 mg. of sesquioxides, primarily Al_2O_3, per 100 grams of soil. These concentrations, however,

appeared below pH 3.6 in one soil (Sharkey clay) with a high silica: sesquioxide ratio, below pH 4.4 in the other soil (Sassafras loam) with a lower silica : sesquioxide ratio. After aluminating the Sharkey soil, injury appeared at pH 4.4, but at pH 4.7–4.8 normal growth was obtained, 4.4 mg. of water-soluble sesquioxides being present per 100 grams of soil. Conversely by silication of the Sassafras loam, good growth could be obtained at pH 3.7–4.0. It is noteworthy that while in the original Sassafras loam the plants were killed when the concentration of the water-soluble sesquioxides (mainly Al_2O_3) was from 18.6–32.0 mg. per 100 g. soil, when this soil had been silicated, survival was still possible with 67.4 mg. of water-soluble sesquioxides per 100 g. soil. Mattson and Hester conclude that possibly aluminum is less toxic when present as a complex aluminosilicate ion than when free. Introduction of SiO_2 from blast furnace slag or comparable sources has been found to be of value in the treatment of agricultural soils containing excessive amounts of soluble aluminum (Taranovskaya, 1939). The minimal injurious concentrations in the experiments of Mattson and Hester certainly indicate an amount of Al in the soil solution far in excess of the threshold doses in solution cultures (for example, 2 mg. per litre recorded as injurious for wheat by Sommer); it has already been indicated that, in soils, the soluble Al is largely present as complex ions, which are possibly less toxic than the Al^{+++} ion. Experiments with water cultures may, therefore, be largely irrelevant to the conditions found in nature. Addition of nutrient salts (K_2SO_4,$MgCl_2$ and $Ca(NO_3)_2$) raised the amount of aluminum in solution, and the pH at which injury appeared, but good growth apparently took place at slightly greater sesquioxide concentrations (4.0–6.0 mg. per 100 g. soil). These experiments of Mattson and Hester indicate that the variation in soluble aluminum due to the colloidal properties of the soil, discussed above, may play a part in determining the growth and so the distribution of plants.

Gapon and Voshchinskaya (1941), in a paper of which an abstract has become available since the first part of this review was printed, conclude that about 90% of the exchangeable aluminum in podzols is present as the oxy-aluminum cation $Al_2O_3H^+$ and that the chloride and particularly the sulphate of this ion are less injurious to wheat than are aluminum chloride and aluminum sulphate.

In general, when a plant is grown in a sufficient concentration of aluminum to produce injury, the element collects in the roots; this has been demonstrated by Magistad for barley and rye, by Eisenmenger (1935) for tobacco, by McLean and Gilbert for corn and cabbage seedlings, by Trenel and Alten (1934) for corn. Ruprecht (1915) found that the toxic effect on clover seedlings was limited to the first few layers of cells of roots in contact with the solution, and believed that the slow death of the plant was due solely to its inability to take up nutrients through the damaged root. This simple explanation is, in light of later work, probably inadequate. The possibility that accumulation in the root interferes with copper metabolism has already been indicated.

McLean and Gilbert found histochemically that in corn and cabbage the accumulation occurred in the cells of the cortex, in the cytoplasm and particularly in the nuclei. The much more resistant red top (*Agrostis alba*) did not, however, accumulate aluminum in this way. In certain pathological conditions, as in the root-rot of beets, abnormal amounts of the element appear in the root (Bodnár, 1914), while in the root-rot of corn (Hoffer and Carr, 1922; Hoffer and Trost, 1923) aluminum and iron both appear to enter the plant and to become deposited in the nodes of the stem. Magistad noticed a decrease in the iron content with rising aluminum and also found that the aluminum content of aerial parts of barley and rye was somewhat increased, though not as much as that of the roots. An increase in the aluminum in the aerial parts of tobacco was also observed in experiments by Eisenmenger, and in stunted pines, suffering from aluminum and perhaps manganese poisoning, by Nemeč and Maran (1939). Other cases of facultative accumulation have already been discussed. In some species, however, marked regulation of the aluminum content of the aerial parts seems to take place. Trenel and Alten found very little, if any, increase in the total aluminum content of the leaves of treated corn plants in spite of the great increase in the aluminum content of roots; no percentage figures, however, are given. Wright (1937) found 0.019–0.024 per cent Al in the dry barley tops, whatever the experimental treatment. Gilbert (in Shear, 1938) states that, while the content of aluminum in the roots of crop plants depends on the available aluminum in the soil, in the tops no such relation is found. Shear's own work, if acceptable, provides a striking ex-

ample of such independence. The presence of very small but often rather constant amounts in the aerial parts can hardly be accidental; some regulatory mechanism must exist, but it is possible that such a mechanism is purely physical, involving only the solubilities of aluminum compounds, and the rate of transpiration.

Interrelationships of aluminum and phosphorus

As has already been indicated, it has been known since the work of Hartwell and Pember that the toxic action of soils, identified as due to aluminum, may be corrected by liberal treatment with lime and with superphosphate. It was natural to conclude initially that the effect of these treatments was either to raise the pH by liming and so precipitate aluminum hydroxide, or to precipitate aluminum phosphate, which is insoluble at hydrogen ion concentrations at which the hydroxide dissolves. Further work has, however, indicated that in the case of phosphate treatment, this simple explanation is not complete. Burgess and Pember (1923) found that after treatment of acid soils with acid phosphate, good growth of barley and of lettuce was obtained but that the aluminum content of such plants was as great as that of those growing poorly on untreated soils, while the phosphate content of the treated plants was much greater. Liming gave less satisfactory growth, though the aluminum content of barley was reduced and the phosphate slightly increased. Comparable results were obtained with lettuce by Pierre and Stuart (1933). When phosphate treatment is used, it therefore seems probable that aluminum precipitates as aluminum phosphate *within* the roots, and in the absence of excess phosphorus causes phosphate deficiency, while liming presumably reduces the availability of aluminum *outside* the plant. Since it has long been known (Lewitsky, 1874; Prianischnikow, 1911; Baguley, 1912; Truog, 1916) that $AlPO_4$ added to sand or soil cultures may be hydrolyzed, producing a basic phosphate of indefinite composition, and free phosphate ions that can supply the phosphorus needs of plants, explanations based on phosphorus starvation are not convincing. Stoklasa (1922; Stoklasa, Šebor, Týmich, and Cwach, 1922) indicates that, in general, phosphorus is low in the ash of the lower vascular plants and mosses, in which he believed aluminum generally to be high. Little reliance can be placed on his findings. Von Faber (1927) found that in species showing a higher aluminum content on solfatara soils than on normal soils, the phosphate content was reduced.

Trenel and Alten (1934) further investigated the relation of aluminum toxicity and plant nutrition, using corn plants, partly grown in very acid solutions containing aluminum with all essential nutrients, and partly in divided root cultures. If a complete nutrient solution is supplied to one half of the roots, and aluminum solution to the other, there is little inhibition of the whole plant, injury being limited to the roots in contact with the aluminum. When one set of roots is fed with phosphate, the other with a phosphate-free nutrient solution containing 1 milli-equivalent or more Al, a great reduction in the dry yield of the plant occurs. The total uptake of phosphorus by such plants is practically unaltered. Phosphorus starvation is, therefore, probably not involved in the inhibition, though the content of the leaves is somewhat reduced and of the roots increased, suggesting, as in earlier work, precipitation of $AlPO_4$ in the roots. In all experiments the total uptake of N, K, Ca and Mg is reduced in the treated plants, but the percentage amount of N, K, Ca and P is actually greater in the dry matter of the experimental plants than of controls. Trenel and Alten conclude, therefore, that in general poor mineral nutrition by the injured roots is not the cause of the inhibition. The magnesium content of the dry matter decreases, however, both absolutely and, save in one series, relatively. In earlier sand culture experiments, Trenel and Frey (1932) had found the uptake of calcium as well as magnesium depressed by aluminum, but that of potassium little affected. Trenel and Alten think that some interference with the assimilative mechanism of the plant occurs as the result of the root poisoning; this conceivably might be due to deficient magnesium uptake, but the data are inadequate to justify any definite conclusion. As has been previously indicated, interference with copper metabolism is also quite possibly involved.

Wright (1937) performed divided root experiments with barley. Only the roots on the aluminum treated side acquired excess of the element, and since the phosphorus was essentially uniform throughout the plant the roots containing much aluminum were supposed to be suffering from phosphorus deficiency. In the most critical experiment, the phosphate-fed roots contained 0.294 per cent P and 0.093 per cent Al, the aluminum-fed

roots 0.244 per cent P and 0.251 per cent Al. The entire aluminum supply of the aluminum-fed roots, therefore, cannot be present as $AlPO_4$, though the excess may well be. In another series where phosphoric acid was used in place of phosphate, the aluminum content of the phosphorus-fed roots was higher than the aluminum-fed which is supposedly due to contamination, but introduces a note of skepticism into a consideration of all the experiments.

Sergeiev and Sergeieva (1939 a, b) recently have claimed that there is a specific antagonism between aluminum ions and phosphate ions. The experiments of these authors on the growth of wheat seedlings are not reported in full, and as they stand are not convincing. The form of the plasmolysis of onion bulb cells in solutions of aluminum sulphate and *o*-phosphoric acid is described and is believed to confirm the conclusions of Szücs (1913) that aluminum increases the viscosity of protoplasm, while the phosphate ion was found to decrease the same. Experiments were also performed on the permeability of the aerial parts of wheat seedlings after growth in solutions of aluminum sulphate, of phosphoric acid, of a mixture of the two, as well as in distilled water. The aerial parts of plants grown on aluminum raised the conductivity of distilled water in which they were immersed, less; those from phosphoric acid, more, than did the controls of plants from mixtures. The water content of the aluminum series was lower (85.3 per cent) and of the phosphoric acid series higher (89.6 per cent) than that of controls (88.5 per cent, mean of four); the water retaining capacity is said to be greatest in the aluminum series. In a second paper the same authors refer to a paper of Znamensky (1927) who found that transpiration may be decreased by aluminum, as Pfeiffer and Blanck (1914) had also observed, while Ivanov (1911) is said to have found the opposite effect produced by *o*-phosphoric acid. Further data are given showing that frost resistance is increased by aluminum and decreased by *o*-phosphoric acid, in a variety of cereals. These results are extremely interesting but it is difficult to form an objective judgment as to their validity, except in the case of frost resistance where fairly extensive percentage data certainly substantiate the authors' case. Such experiments lend more support to the inference from Stoklasa's investigations as to the possible rôle of aluminum in water metabolism, than did his own doubtful analytical data.

The beneficial effects of calcium have been less studied. Wright reports some improvement of the growth of beets by the addition of calcium lactate, which did not change the pH of the acid soil employed. No data are given of the yields obtained, but liming, which raised the pH from 4.32 to 6.38, was evidently much more effective.

Aluminum and the coloration of plants; the blue Hydrangea

Soon after the introduction of the cultivated Hydrangea (*H. macrophylla* DC.) into England in 1790 by Sir Joseph Banks, and by Mr. Slater about the same time, it was noticed that the pink petaloid sepals sometimes tended to become blue in a manner that at first appeared unpredictable. Curtis (1799), who figured a pink plant, noted that in 1796 this change was observed in a plant "in the possession of the Countess of UPPER OSSORY, whose refined taste and superior judgement have in several instances contributed to render our works more acceptable to the public". (Anne Fitzpatrick, Countess of Upper Ossory, is best known as a correspondent of Horace Walpole; she died in 1804.) The cause of the variation was sought by horticulturists and physiologists for over a century. Though an empirical method for producing the more esteemed blue flower was early developed, no completely satisfactory elucidation of the problem appeared until 1937 when Chenery published what is probably the best work yet to appear on the rôle of aluminum in the biochemistry of any plant. The history of the problem is fully covered by Chenery, whose account is the basis of the present summary. There is evidence that between 1800 and 1815 various attempts to modify the color with peat and wood ashes were made. In 1817 Sprengel claimed that the addition of iron salts to the soil on which plants were growing produced the blue color. This claim has been revived a number of times. Shortly afterwards, in 1822, J. Busch, the gardener to the Emperor of Russia in St. Petersburg, discovered that by watering the plants with a solution of alum, fine blue flower heads could be obtained, adding with considerable perspicacity, "Our gray colored earth under the black moor earth will have the same effect, being combined with aluminuous salt." Such a use of alum is mentioned by Loudon in 1827 and 1835, though it is clear that various acid and yellow soils were also used in the early part of the nineteenth century and that the effect was generally attributed to iron. The

obvious presence of hydrated ferric oxide in the acid soils that produced blue flowers has continually led to statements, summarized by Chenery and still repeated by gardeners both in the United States and in England, that iron is responsible, in spite of the fact that as early as 1821 Schübler showed that such soils did not necessarily contain more iron than those on which the pink form is found (see also Schübler and Lachenmeyer, 1834).

Donald (1846) made systematic experiments with both iron salts, alum, and other substances, obtaining blue flowers only when alum was used. Half a century later the problem was again studied by Molisch (1897) and by Vouk (1908). Both investigators found that while potash alum, aluminum sulphate, and ferrous sulphate are effective in varying degrees, such large amounts of iron were needed to produce blue flowers that the vegetative parts of the plant were seriously affected. Both investigators concluded that potash alum was the best agent in horticultural practice. Stoklasa (1922) considered that aluminum was actually involved. Connors (1923) and Coville (1923) later recommended aluminum sulphate as suitable in American horitcultural practice. Allen (1931, 1934) who tried the effects of acids as well as ferrous and aluminum sulphates and potash alum on pot cultures, found aluminum sulphate the only really effective agent, though bluish pink flowers were produced by the iron salt. Raber (1933) mentions the action of aluminum as a remarkable metabolic effect of the element. Chouard (1933) claimed that chromium was even more effective than iron or aluminum, and later (1934) that uranium sulphate produced blue flowering plants with very deep green leaves.

The introduction of the study of hydrogen ion concentration naturally affected the problem. Atkins (1923) found that soils below pH 6.0 produced only blue flowers, above 7.5 only pink flowers. He supposed that addition of aluminum sulphate acidified the soil and so liberated iron. Connors regarded the critical pH for color change as 6.2, Wiggin and Gourley (1931) about 5.0. Above 6.0 the flowers were invariably pink and the plants slightly smaller. In Chenery's observations exclusive production of blue flowers occurred only at or below pH 6.3. Atkins found that the cell sap of blue and of pink sepals from the same plant lay between 4.0 and 4.2. Connors found pink flowers grown on limed soil had a slightly less acid cell sap than blue or white. Chenery found values between 4.3 and 4.75 for both blue, pink and purple flowers. This essential constancy of reaction, and the fact that if the anthocyanin were acting as an indicator it would be red in the more acid part of the range, exclude any explanation based on hydrogen ion concentration.

In opposition to Atkins' view that the blue color was probably produced by the acidity, induced by aluminum salts, liberating iron, Allen (1934) concluded that high "available" aluminum in acid soils was responsible for the blue color. Chenery showed that in general blue flowers grew on soils whose displaced solutions contain at least 0.01 p.p.m. ionic aluminum and usually much more. No ionic iron was found, nor any correlation of blue color with total iron in the soil solution. Addition of aluminum sulphate to a soil did not increase the total iron of the solution. Molisch, however, found that treatment with both ferrous and aluminum sulphate caused pink flower pedicles to become blue. Robinson (1933) produced blue flowers by placing the stalks in very dilute ferric chloride. Spraying intact plants, Allen found aluminum sulphate alone to be effective. Finally Chenery isolated the pigment, which Molisch and Allen were unable to obtain, as an anthocyanin acetate. Cobalt, chromium, copper, manganese, nickel, and uranium failed to give a blue color with a solution of this pigment; iron gave a greenish blue color, aluminum alone a clear blue.

The earlier analyses of the plant were confined to Yoshii and Jimbo's qualitative study and determinations of iron made by Atkins and by Manly (*fide* Chenery). The latter authors obtained slightly more iron in the blue flowers than the pink. The only quantitative determinations of aluminum are due to Chenery and are very striking. The aluminum content of blue flowers or sepals ranges from 326 to 2,710 mg. per kilo. of dry matter, the mean of twenty-one analyses being 943; the content of pink, white or red flowers ranges from 29 to 109 mg. per kilo. dry, the mean of eleven analyses being 59.9. The mean iron contents of the two groups are respectively 166 and 135, so that the ratio of the mean Al to mean Fe is 5.68 in blue and 0.445 in other flowers. The pedicle of blue flowers has a slightly greater mean Al content than the sepals; in pink flowers the relation between the much reduced Al contents is reversed. In blue flowering individuals the whole plant is much richer in Al than in pink plants, the mean content for leaves being forty times as great in blue as in pink. The

absolute quantity occasionally is as great as 12,800 mg. per kilo. (1.28 per cent) Al in the dry matter and usually over 1000 mg. per kilo. Such figures indicate the plant to be a pronounced facultative accumulator of aluminum. Aluminum-treated plants mainly store the element in the leaves, and continual removal of dead leaves from a potted plant could thus remove the available aluminum from the limited supply of soil, causing a change from blue to pink in the course of a few years. The reverse change might occur if the plants were watered with acid water, and the small supply of calcium leached from the pot, so that the soil became acid and rich in soluble aluminum. Analyses of blue and pink flowers from the same plant show 1.20 to 2.49 times as much Al in blue as in pink flowers, while in the series studied by Chenery the iron content of the blue flowers was never greater and usually less than that of the pink. The critical aluminum content to produce a blue flower is about 170 mg. per kilo. dry. With these facts available, we may conclude with Chenery, that the blue pigment of *Hydrangea macrophylla* is an aluminum compound of the rather unsatisfactorily characterized delphinidin diglycoside found in the flowers by Robinson and Robinson (1931, 1932, 1933, 1934).

An experiment reported by Kraemer (1909) in which blue flowers were produced by treatment of sand cultures with potassium carbonate must remain problematical. The effect was not obtained in soil cultures. If an adequate source of aluminum were present in the sand, that change might formally be attributed to the production of the easily soluble potassium aluminate; it is, however, improbable that the plants would flourish in so alkaline a medium. Little effect on the color of roses, violets, or carnations is produced by treatment with aluminum, iron, or potassium (Kraemer, 1906).

Kratzmann (1914) found that 0.01 per cent aluminum nitrate added to Knopf's solution caused red cabbage to produce a blue anthocyanin. The effect, which, as in the case of *Hydrangea*, cannot be due to pH, was not obtained in soil cultures. Cut twigs of red varieties of *Betula* and *Corylus* also produced blue pigment when set in aluminum solutions. Negative results, however, were obtained with *Beta* and *Achyrantes*. This is explained by Kratzmann as due to the presence of a different anthocyanin in these plants; it is now well known that the red color of beet is due to an entirely different type of pigment (betanin) from that usually present in red flowers.

Stoklasa (1922) on the basis of experiments on *Matthiola annua*, *Papaver somnifera*, *Nicotiana longifolia*, *Rhododendron indicum*, and *Fuchsia* sp., reported with somewhat unconvincing colored figures, claimed that treatment of plants with aluminum salts very generally tended to intensify floral color, and to convert white flowers to red, red to violet or blue. He also concluded from analytical data that in plants, insects, and birds, bright coloration is associated with a high aluminum content of the colored structures. He attributed this supposed correlation to the alleged rôle of aluminum as an oxidative catalyst. The uncertainty attending Stoklasa's analytical data makes it impossible to accept these results. Wittstein (1867) gives analyses of the leaves and flowers of white and purple lilac trees (*Syringa vulgaris*), which

	Leaves		*Flowers*	
	Per cent Al ash	*Per cent Al dry matter*	*Per cent Al ash*	*Per cent Al dry matter*
White.....	0.105	0.0046	0.073	0.0042
Purple.....	0.101	0.0050	0.129	0.0056

provide some, but no very great, indication of accumulation in the purple flowers. Wittstein does not discuss his aluminum data, but points out that while the leaves and flowers of the purple variety contain appreciable amounts of manganese, that element is apparently lacking in the white variety. Though a genetic basis for the color difference presumably exists in this case, it is possible that further examples, comparable to the blue *Hydrangea*, may be found involving not only aluminum but also other metals. Shibata, Shibata and Kasiwagi (1919), have prepared a number of metallic complexes of anthocyanins, the colors of which vary with the metal used.

Some authors have supposed that the presence of aluminum in preparations of natural dye-stuffs indicates the presence of aluminum lakes in both plant and animal organisms. Thus Rüdiger (1914) regards Lo-kao or Vert-de-Chine as existing in *Rhamnus utilis* as a calcium-aluminum lake of locaonic acid, a rhamnoside of locanic acid. The analytical evidence for this belief, however, is meagre. Among animal products, a more likely case of a natural lake is provided by the carmine of cochineal. Liebermann (1885) found in the purest commercial material on an average about 7 per cent ash of which 43.09 per cent is Al_2O_3 and 44.85 per cent CaO. He believed the dye-stuff to

exist as an aluminum calcium protein complex. There is, however, no clear evidence that such a complex actually exists in the bodies of the *Coccidae* containing the pigment and Dieterich (1867) had previously found the ash of cochineal to be mainly sodium and potassium phosphates, with only 1.39 per cent Al_2O_3. No recent investigation, on properly determined material, seems to have been undertaken.

Organic aluminum compounds in plants

Apart from the occurrence of aluminum succinate in *Orites*, already mentioned, and the aluminum delphinidin complex and other pigments discussed in the preceding section, there are a few old records supposedly indicating organic aluminum compounds. Yoshida (1883, 1887) found about 6.3 per cent of the ash of Japanese lacquer, the latex of *Rhus vernicifera*, to be alumina. This he concluded, was present as "aluminum arabate." Church noted likewise a little aluminum in the ash of some samples of cherry-gum and of gum arabic (1888a, b) and in gum tragacanth (1888a). Young (1888) found that the small amount of aluminum (0.45 per cent Al_2O_3, apparently present as phosphate, in the ash) in wheat flour was intimately associated with the gluten fraction, suggesting an aluminum protein complex. None of these cases are particularly illuminating. The existence of organic salts of aluminum in *Lycopodium* has been previously mentioned. No satisfactory information exists as to their identity; aluminum forms complex ions with certain organic acid radicles, but the most obvious of these, the aluminoxalate and aluminicitrate ions, have not so far been reported from plants.

Palaeobiochemistry of aluminum

Many authors have supposed that the composition of coal ash gives evidence that aluminum accumulation was widespread in the Palaeozoic flora. Vohl (1862), in a paper that it has not been possible to consult, compared the composition of the ash of fresh *Sphagnum commune* with that allowed to decay under water, and found that while the alkalies were lost, the relative quantities of lime, alumina and ferric oxide were greatly increased in the decayed plants. Thorpe (1878) who quotes Vohl's results, also compared coal ash with that of the species of *Lycopodium* studied by Aderholdt and concluded that, as *Lepidodendron* and other important Coal Measure plants were then regarded as *Lycopodiaceae*, the rather large amounts of alumina (28.7–33.8 percent) reported from British coal ashes were derived from these plants. Church (1888b), however, was skeptical of this conclusion, largely because it had been found by the time that he wrote that the relationship of the fossil Lycopodiales of the Coal Measures to the genus *Lycopodium* was by no means as close as was formerly believed. The hypothesis is, however, considered as possible by Hinrichsen and Taczak (1916), Lessing (1920), Stoklasa (1922), and Vinogradov (1935a). The last two authors, partly on the basis of Stoklasa's very doubtful analyses, concluded that in general the archaic plants, likely to be distantly related to the members of the Carboniferous flora, contain a greater quantity of aluminum than is found in the members of the more specialized modern groups. Vinogradov, indeed, considers that the lower organisms tend to have a more diversified elementary composition than do the higher groups and that aluminum is but one of the elements that are becoming biochemically extinct.

While many coal ashes are known to be high in aluminum, there is clearly great variability in this respect. Goldschmidt and Peters (1933b) conclude that aluminum is somewhat enriched in coal ash but much less so than many rarer elements. In the table of analyses of nineteen coal ashes given by Hinrichsen and Taczak, there are, as well as ashes much richer in silica than in sesquioxides, others in which Al_2O_3 is the dominant component, and yet again a third group much richer in ferric oxide than in either silica or alumina. All observed compositions might be explained in terms of admixtures with material resembling the inorganic fractions of modern tropical soils. Apart from such analyses in which the mineralogical composition of the coal was not considered in detail, a very important study has been made by Lessing (1920), which study does appear to give evidence in favor of the view that certain of the important plants of the Coal Measures were aluminum accumulators. Lessing studied the ash components of specimens of the four organic constituents recognized by Stopes (1919) as comprising the banded bituminous coal of the Thick Coal, Harnstead Colliery. These four constituents differ widely in their ash content, two of them, *fusain* (ash 4.48–16.70 per cent) and *durain* (4.94–7.22 per cent) have a high proportion of ash, the other two, *clarain* (0.91–1.58) and *vitrain* (0.98–1.22) a low ash content. In the first

two the ratio Al_2O_3/SiO_2 is respectively 0.98 and 0.84, essentially as in kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ gives 0.85). On the other hand, the ratios for the other two constituents are widely different, as is shown by the following analyses:

	Clarain	*Vitrain*
SiO_2	9.44	6.08
Al_2O_3	16.58	15.49
Fe_2O_3	3.31	3.09
MnO	0.23	0.13
TiO_2	0.50	0.24
CaO	12.98	15.22
MgO	10.52	1.87
Na_2O	15.71	17.69
K_2O	—	0.20
SO_3	32.18	30.89
P_2O_5	0.01	tr.
CO_2	—	6.69

The ratios of silica to alumina in the constituents of coal, analyzed by Lessing, and in comparative material of interest are as follows:

	SiO_2 :	Al_2O_3 :	Fe_2O_3
Accessible lithosphere	100 :	15.36 :	7.13
Kaolinite	100 :	85.0 :	—
Fusain	100 :	97.8 :	38.1
Durain	100 :	83.8 :	2.55
Clarain	100 :	176 :	35.1
Vitrain	100 :	255 :	50.8
Lycopodium flabelliforme: ratio of means	100 :	422 :	5.9
L. complanatum vars. *tropicum* and *validum:* ratio of means	100 :	292 :	1.8

Lessing tentatively compares the ratios SiO_2/Al_2O_3 with the ratios of the means for Ritthausen's, Aderholdt's, and Church's analyses of *Lycopodium*, namely 100:292. Since the species and varieties differ greatly in their silica content, and in their capacity to retain contaminant soil, the *Lycopodium* ratios given above have been calculated for a very strong accumulator, which in general is easily obtained free from much extraneous silica, and for an allied tropical group of varieties that have a greater or less development of a silica skeleton. It will be noticed that while the ratios for *fusain* and *durain* give no evidence of the presence of any aluminum other than clay minerals comparable to kaolinite, in *clarain* and still more in *vitrain* a great enrichment of aluminum has occurred, the latter approaching the ratio exhibited by the tropical varieties of *L. complanatum*. Lessing found that in *clarain* and still more in *vitrain* ash a large part of the aluminum was soluble in HCl, and therefore presumably present as Al_2O_3 and not as a silicate. This more detailed study so far certainly suggests the presence of aluminum accumulators in the flora of the Coal Measures.

When, however, the data for iron is examined, another explanation for the phenomenon suggests itself. In both the materials enriched in aluminum, the iron content is high. Admittedly this is also the case in *fusain*, which makes interpretation difficult. The ratios of aluminum to iron in *clarain* and *vitrain* are practically identical and essentially as 5:1, suggesting a similar mode of origin; moreover, the highest ratio of these elements relative to silica is not in *clarain* which retains microscopic evidence of plant structure, but in *vitrain* which appears to have been formed as a homogeneous gel. It has, however, been pointed out that in *Spagnum* and in the sheaths of *Leptothrix* considerable quantities of both elements occur. If Kalinenko is correct in ascribing the bacterial accumulation of iron primarily to adsorption, it is clear that an alternative explanation, that the sesquioxides of the low ash components of coal were largely adsorbed *postmortem* on structural coarse detritus (*clarain*) or colloidal micelles of humic material (*vitrain*), is possible. It is true that in the known cases of this process, the ratio $Al_2O_3:Fe_2O_3$ is less than 5:1, usually being in favor of iron, just as in the known cases of aluminum accumulation of a strictly biological nature, the ratio favors aluminum much more than in the *clarain* and *vitrain* ashes. The iron content of the latter materials, while suggesting that biological accumulation is not the only major factor involved, therefore, does not distinguish sharply between the two most likely hypotheses.

Goldschmidt and Peters (1933b) have studied the minor constituents of a number of coal ashes; unfortunately they do not give any original data on the commoner elements. From the standpoint of the present review, the gallium content of coals is of particular interest, gallium being the element most likely to behave like aluminum and iron. In German coals, in general, this lies between 0.01–0.001 per cent Ga_2O_3 in the ash; one English coal, rich also in germanium, contains 0.05 per cent. There seems to be no difference between German durain and vitrain-clarain samples in this respect. In Silesian coals, the gallium content appears to be about 0.01 per cent; in various samples of peat and humus, about 0.001 per cent Ga_2O_3 is present. It is very unlikely that

in the samples of bituminous coals studied, the ratio of Al:Ga is ever less than 100:0.01 and often it must have been nearer 100:0.1. In *Lycopodium flabelliforme* a ratio of 100:0.001-0.002 is found. It is not unlikely that both the iron and gallium of coals are secondary, but in so far as the data of Goldschmidt and Peters are relevant, they do not seem to support the hypothesis of extensive aluminum accumulation by the chief plants of the flora of the coal measures.

It must, however, be emphasized that whatever solution be ultimately obtained, there is little reason for the belief that there has been a *progressive* decrease in the biochemical importance of aluminum throughout geological time. The capacity to accumulate large amounts of the element has clearly been acquired by certain species of *Lycopodium* during the evolutionary history of the genus. The sporadic distribution of groups of species or genera of aluminum accumulators among both Pteridophytes and Spermatophytes suggests a number of independent appearances of the property, though it is just possible that accumulation occurs slightly more frequently among the ferns than among the seed plants. Lehmann's and Meunier's results, already summarized, indicate no accumulation in marine algae. As far as the available data permit a conclusion, the same is also true of fungi. Some mosses may accumulate the element, but the evidence for most species is still inadequate. In as much as there is a number of isolated cases of aluminum accumulators among the Pteridophytes, the possibility that some plants of the Coal Measures, of the same order of complexity as the modern ferns and their allies, did accumulate the element cannot be lightly dismissed, but it is far from proved. Vinogradov's more extensive generalization, though interesting, rests on even less secure foundations.

Supposed plant indicators of alum deposits

In the *Commentarii* of Pope Pius II (Aeneas Silvius Piccolomini) is given (ed. Frankfurt, 1614, p. 195) a dramatic account of the discovery of a deposit of alum near Civita Vecchia, by Giovanni di Castro, between 1460-1470. The locality was in the hills of Tolfa, "*per quos dum Ioannes ambulat, novam herbae faciem offendit: miratur, inquirit; deinde certior fit similem nasci herbam in montibus Asiae, qui Turcarum aerarium alumine ditant:*" It would seem, therefore, that Giovanni di Castro, who had had experience of the alum deposits in the Near East, recognized his discovery, which proved of considerable political and economic importance, by means of an indicator plant. Though the text suggests some low growing species, there appears to have been a persistent tradition in Italy during the seventeenth and eighteenth centuries that the European holly, *Ilex Aquifolium*, was associated with alum deposits. In the curious *Phytosophicae Tabulae* of Federigo Cesi, Duke of Acquasparta, added to Recchi's edition (Rome, 1651) of Francisco Hernandez' famous *Nova Plantarum, Animalium et Mineralium Mexicanorum Historia*, there is an entry (p. 911), "*Siquidem diversae, diversis halitibus exurgunt Plantae. Aluminois Agrifoliũ gaudet cuius plantae indicio alumina in Thuscia Graecus invenit, quae suis in regionibus eiusdem Plantae sylvulis subessent.*" This presumably refers to the discovery at Tolfa, though the plant has obviously grown taller in the hundred and eighty years that have elapsed. Boccone (1697) in his *Museo di Fisica*, a collection of letters on various aspects of natural history and medicine, addressed to eminent persons, writes (p. 152), "*E opinione in Italia, che dove nasce l'Agrifolium ivi si trovi sovente la Miniera dell' Alume.*" Since Boccone, who was obviously uncertain of the validity of the opinion, later (p. 249) suggests that the belief might be tested at Tolfa, it is improbable that he considered the indicator plant of the *Commentarii* to be *I. Aquifolium*; indeed he does not seem to have known of the story of Giovanni di Castro. Much later Targioni-Tozzetti (1774) discredits the association of alum deposits with holly trees, "*e che questo servisse d' Indizio allo Schiavo Turco, per scoprire le Allumiere della Tolfa.*" Targioni-Tozzetti had observed both alum without holly trees and the holly trees without alum. The story is repeated, with full documentation, by Beckmann (1784) who asserts, without evidence, that di Castro's plant was *Ilex Aquifolium*, and, from Beckmann's book, was included by Muspratt (1853) in a well-known encyclopediac work on applied chemistry. A German edition of Muspratt's work was reviewed by Wittstein (1855a) who comments on the matter in his notice, and shortly after, the question of aluminum accumulation in the holly was at last investigated, with an essentially negative result, by Reithner (1855) in Wittstein's laboratory, as is indicated below. Mellor (1929) dismisses the story of the association, and von Linstow (1929) has no mention of the matter in his invaluable treatise on indicator

plants; Robinson (1938), however, believes the tradition to be of interest in that he has found rather more alumina in American holly (*I. opaca*) than in other plants growing on the same soil. It is very probable from the statements quoted from the earlier Italian writers that the belief in the value of holly as an indicator originally had nothing to do with the Tolfa deposit. Long after the nature of the low growing plant observed by di Castro had been forgotten, the common belief may have been grafted onto his history and a Turkish slave invented to lend a flavor of magnificence to the tale.

Professor Leona C. Gabel, of Smith College, kindly indicates (*in litt.*) that the Vatican manuscript version of the *Commentarii*, which is often more explicit than the later printed edition, provides no further information that could lead to an identification of di Castro's indicator plant.

As has previously been stated, Hallier gives *Ilex Aquifolium* in his list of plants which, from their yellow-green color when dried, are supposed to look like aluminum accumulators. However, Reithner noted but 0.35 per cent Al in the ash or 0.013 per cent Al in the dry leaf, while Hutchinson and Wollack find, in a leaf from a herbarium specimen from the French Jura, not more than 0.2 per cent Al in the ash or 0.0070 per cent Al of the dry matter, which is very little greater than the amount present in normal flowering plants. Yoshii and Jimbo record doubtful indications in *I. crenata* var. *typica* f. *genuina* Loes, probably corresponding to less than 1 per cent Al in the ash. These data, however, do not exclude the possibility that *Ilex* may be specially tolerant of aluminum, accumulating aluminum, if at all, only in the root, which possibility might, in view of the tradition discussed, and of Robinson's remark, be worthy of investigation, though no modern records of holly on alum-containing soils seem to have been published.

A somewhat similar story is associated with the earliest alum works opened in England, near Whitby. Camden (1610, p. 721, Philemon Holland translation) says of the place, that it

> richly aboundeth with vaines of mettall and Alum-earth of sundry colours, but especially of ocher and murray, likewise of iron, out of which they have now begunne to try very good Alum, and Coperose. Which with learned skill and cunning not many yeeres since, Sir *Thomas Chaloner* Knight (a learned sercher into natures workes, and unto whose charge, our most high and mighty King hath committed his sonne Prince Henrie, the lovely joy and delight of Britaine) first discovered, by observing, that the leaves of trees were of a more weake greene colour heere than in other places; that the oakes had their rootes spreading broad but very eb within the ground, the which had much strength but small store of sappe, that the earth standing upon cley, and being of divers colours, whitish, yellowish, and blew, was never frozen, and in a cleere night, glittered in the pathes like unto glasse.

The passage is not in the Latin edition of 1600; Beckmann quotes a later edition, not seen by the present writer (Gibson's third edition, 1753) in which the date (an 1607) is inserted. In Gibson's first edition, 1695, there is a marginal note to the "leaves of trees" reading "magis subvivere," but no Latin edition containing the story seems to exist. All the editions vary; Gibson's lack the richness of Philemon Holland's magnificant prose. The passage is given here in full as it represents the first clear indication to be printed of any ecological effect of an aluminum compound. Pennant (1771, p. 21-22) adds that there was a tradition that Sir Thomas seduced some workmen from the Pope's alum-works near Rome, no-one in England understanding the operation of the enterprise, and that if "one may judge from the curse which his Holiness thundered out against Sir Thomas and the fugitives, he certainly was not a little enraged; for he cursed by the very form that *Ernulphus** has left us, and not varied a tittle from that most comprehensive of imprecations." Pennants' asterisk refers to a footnote "*Vide *Tristam Shandy*."

(*To be continued*)

SEXUAL DIFFERENTIATION IN MOLLUSKS

I. PELECYPODS

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AMONG the more than 10,000 species representing the class Pelecypoda may be found every grade of sexual differentiation, from species that are strictly of separate sexes to those that are almost invariably functionally hermaphroditic. Even two species belonging to the same genus may differ considerably in sexuality. And in a relatively few species the functional sexual phase of some or of all the individuals may change during the animal's lifetime. Indeed there are some species in which nearly every normal individual experiences several alternating male and female sexual phases. Hermaphroditism may likewise be complete, partial or occasional.

Because of these wide variations in the expression of sexuality, not only in different species but in different individuals of the same species and at different periods of life, the bivalve mollusks promise to offer evidence of some importance toward an understanding of the general problem of sexuality in organisms. This evidence must be examined as to its bearing on embryology, physiology and genetics.

Except in those species that are strictly of separate sexes (unisexual, or dioecious) the gonad contains the antecedent cells of both eggs and sperm. As a general rule the male cells mature in advance of the female cells, whereby the initial phase of functional sexuality is male. Such individuals are said to be protandric. Less frequently the initial phase is female and the individual is proterogynous. In functional hermaphrodites the eggs and sperm develop concurrently.

When each normal individual experiences two or more alternative sexual phases it is quite illogical to treat the sperm-producing and egg-producing stages as males or females as if they were distinct categories of individuals. They are merely temporary phases in the life of the same individual. Furthermore the proportions of individuals in each of these phases after the first would seem to have less significance than some investigators have supposed, since it is obvious that if twice as many individuals are found in one of these phases as in the other, that may be merely an implication that one of the phases lasts twice as long as the other. It might also mean that some are older than others.

The sexual conditions in the pelecypods are sometimes further complicated by the occurrence of neoteny, or juvenile sexuality. In such cases the individual may form a small number of gametes when it is very young and only a small fraction of its definitive size. This juvenile phase may may be more or less aborted and, as mentioned on the following pages for *Venus* and *Ostrea* may be of a different sexual type than that found in the adult. Consequently the sexuality of a species can be determined only by the examination of numerous individuals at all periods of life.

At the outset it must be recognized that the process of changing from one sexual phase to another is usually, but not invariably, gradual, with an intervening phase during which the gonad presents all possible grades of hermaphroditism, or ambisexuality. Since in many species it is impossible to examine the gonad of any one individual at successive stages of its life, it becomes necessary to infer its history from an examination of other individuals at different ages. These individuals, if protandric, might be erroneously thought to be males if examined when young, females when older, and hermaphrodites during the stage of sexual transformation. They represent, on the contrary, merely the sexual phases experienced by each normal individual during its lifetime.

In some species, however, definite proof of the number of changes of sexual phase experienced by any individual can be obtained by marking the shell and observing the sexuality at succeeding spawning periods. This is likewise feasible with gastropods. But with other forms, as the wood-boring bivalves, that is not possible and recourse must be had to observations of the gonads of many different individuals of known ages. In the larviparous species the presence of embryos or larvae in the gill chambers or mantle cavities is sufficient evidence as to the character of the preceding sexual phase.

With these facts in mind a brief survey of the sexuality of the whole group of bivalves may be undertaken. For more than half the total number of described species the sexual conditions are quite unknown or undescribed. For the others, approximately 96 per cent are reported as of separate sexes or that type of sexuality is inferred. Less than 400 of the 10,000 described species are known to deviate from a strictly dioecious, or unisexual, condition, except for an occasional case of hermaphroditism due to an abnormality of development. Of those species that are normally monoecious (hermaphroditic, bisexual, ambisexual) some are uniformly functionally hermaphroditic, producing eggs and sperm at the same time, while others show various grades of mixed sexuality or changes in sexuality at some period of life.

The pelecypods have no copulatory organs or other external sexual characteristics, with the exception that in certain dioecious species of *Unio*, *Astarte* and a few other genera the two sexes, when adult, can be distinguished by the shape of the shell. Otherwise it is necessary to examine the gonad unless it is possible to observe the individual during the act of spawning. Accessory sexual organs are absent with the exception of the seminal vesicles, found only in *Xylophaga* and *Cuspidaria*, and the brood chambers on the gills of various larviparous species.

DEVELOPMENT OF PRIMARY GONADS

The sexuality of any individual obviously depends primarily upon its hereditary characteristics and these first find expression in the gonads. Consequently the history of the gonads must be followed in order to obtain reliable information relative to the prospective sexuality of any individual.

The primary gonads arise from a pair of germinal primordia situated in the posterior portion of the body, ventral to the pericardium and in close proximity to the visceral ganglia and the renal organs. Each of the primordia develops into a profusely branching system of follicles surrounding the intestine in the mesosoma, or visceral mass. In the mussels the gonads extend also into the mantle lining both valves of the shell and in *Anomia* into the mantle on the right side of the body.

The constituent cells of each follicle soon become differentiated into nutritive follicle cells and primary gonia. If the individual is to become hermaphroditic the primary gonia soon give rise to cells of two types, clearly distinguishable as spermatocytes and ovocytes. But even in dioecious species there may be indications of ambisexuality in the primary gonad and some ovocytes are often formed in the early spermary. Such ovocytes undergo cytolysis during spermatogenesis.

A. AMBISEXUALITY: MONOECISM

For convenience of reference the various grades of ambisexuality may be considered as consisting of the four following categories: (1) functional ambisexuality (functional hermaphroditism), (2) consecutive sexuality, (3) rhythmical consecutive sexuality, and (4) alternative sexuality. Since the terms "bisexual" and "bisexuality" as currently used by different writers may indicate either a monoecious condition of an individual or a dioecious condition of a species they may well be avoided. The term "ambisexual," if used strictly with reference to individuals having gonads composed of both male and female sexual cells, is less ambiguous than either bisexual or hermaphroditic.

1. Functional ambisexuality (Functional hermaphroditism)

Functional hermaphroditism is found in nearly all phyla of invertebrates and in every phylum of plants. There is here no incompatibility between the male and female sex organs and both types of sexual cells may be produced simultaneously. Not infrequently, however, this condition is preceded by a brief period of maleness or occasionally of femaleness. In some of these species the extent of protandry is increased by unfavorable conditions and can be controlled experimentally.

(*a*) *Normal.* This implies a strictly monoecious, or ambisexual, condition, with the con-

current production of gametes of both sexual types by each individual. In some species the male and female elements are in separate gonads, with separate efferent ducts; in others there are male and female portions of a single gonad, while still others have both spermatogenic and ovogenic cells in the same follicle. A tendency toward protandry is general but some individuals discharge both types of gametes at the same time and some of the eggs are capable of self-fertilization.

Among the better known of the strictly hermaphroditic pelecypods are certain species of *Pecten*, *Gemma*, *Tridacna*, *Tivela*, *Anodonta*, *Kellia*, *Thracia*, and other genera of the suborder Anatinacea, *Cardium*, *Pisidium*, *Sphaerium*, *Musculium*, *Poromya*, *Silenia*, *Cyclas*, and at least one species (*Teredo diegensis*) of the wood-boring bivalves. In a considerable proportion of these the eggs are fertilized within the mantle cavity and the young complete development to the adult form in brood pouches on the gills of the parent.

The ribbed scallop (*Pecten irradians*) may be taken as a typical example of functional hermaphoriditism. In this and other species of the genus the spermatic tissues occupy the dorsal portion of the gonad and the ovarian tissues the much larger ventral portion. The two portions are not demarcated morphologically but are readily distinguished in sexually mature individuals because of the differences in color, the spermatic tissues being creamy white and the ovarian tissues deep pink. Both eggs and spermatozoa are discharged through the same efferent ducts.

Both types of gametes mature at about the same time, although there is a tendency toward protandry, and a considerable portion of the sperm will usually be discharged before any of the eggs are spawned. In other individuals both eggs and sperm are discharged simultaneously and self-fertilization may sometimes occur (Gutsell, 1931). In nature the spawning of one individual, followed by the presence of gametes in the water presumably initiates a corresponding reaction in many other individuals in the vicinity. Simultaneous spawning and cross fertilization will then be general in the population. Furthermore, certain individuals appear to be self-sterile.

In other species of the same genus, as *P. opercularis* and *P. maximus*, some individuals are distinctly protandric at each spawning season, nearly all of the sperm being discharged before the eggs of the same individual become fully ripe. Other individuals are evidently proterogynous. There is thus a brief period when the individual is morphologically hermaphroditic but functionally male and another period when it is functionally female, with an intervening stage when it is functionally hermaphroditic. A similar condition is found in *P. latiauritus* var. *monotimeris* on the coast of Southern California. Protandry is more frequent than proterogyny. This type of sexuality is consequently intermediate between such forms as are strictly hermaphroditic and those that experience consecutive male and female sexual phases.

In one species (*Teredo diegensis*) of the wood-boring mollusks most of the mature individuals are functionally hermaphroditic, following a primary protandric phase. The gonads at all seasons of the year on the coast of Southern California usually contain ripe sperm and mature ova. Experimental self-fertilization is often successful. Larvae are present in the brood chambers of the gills at all seasons of the year. In addition to the larviparous hermaphrodites the population contains a very small percentage of individuals known as true males. In the latter the ovocytes are aborted.

The successive sexual phases of this species may be indicated by the following schematic representation:

Primary male phase ... True male (exceptional) ...
Primary male phase ... Functional hermaphrodite ...

In a species of cockle (*Cardium corbis*), of the Pacific coast, the eggs and sperm are produced simultaneously in adjacent follicles of the gonads (Edmondson, 1920). This is the case also with *C. crassum* and *C. serratum*, although *C. edule* is dioecious. The Pismo clam (*Tivela stultorum*) is hermaphroditic, but as a general rule the sperm and eggs do not mature at the same time (Weymouth, 1920). Consequently the conditionsare seldom favorable for self-fertilization. There is a general tendency toward protandry, for the hermaphroditic condition of the adult is frequently preceded by a primary male phase in young individuals.

(*b*) *Accidental or developmental.* Even in species which are otherwise strictly of separate sexes there may be an occasional individual with functional hermaphroditism. These can all be considered as

resulting from deviations in the developmental processes due to the failure of the sex-differentiating mechanism to function normally. The proportion of spermatogenic and ovogenic tissues in the gonad is highly variable, some individuals having approximately equal parts of both sexual types, while others are principally of one sex, with but a few cells characteristic of the opposite sex. This type of sexuality is more common in the pelecypods than in most other groups of animals and it occurs most frequently in young individuals at the first reproductive season. In certain local races of oviparous oysters, clams, and mussels it is impossible to determine whether the initial sexual phase is normal or accidental hermaphroditism.

2. *Consecutive sexuality*

This type of sexuality implies a single change in the functional sexuality of the individual, or sex reversal. The male and female phases may intergrade or they may be sharply separated. Consecutive sexuality is of wide occurrence, being found not only in most classes of mollusks but in other phyla of invertebrates, including annelids, echinoderms, nemerteans and crustaceans, as well as in some plants and a few fishes. Most of the invertebrates of this type experience but a single change of sex, usually from male to female. An overlapping of the two sexual phases may produce a brief period of hermaphroditism, at which time self-fertilization may occur. Other representatives of the same groups may experience a rhythmical sexuality, with regularly alternating male and female phases.

The histological basis of this type of sexuality depends upon the presence of an essentially ambisexual gonad, associated with a hereditary mechanism which causes the activation of one of the two types of sexual cells in advance of the other.

Consecutive sexuality may become manifest during a single spawning season, one sexual phase following the other without an intervening period of recuperation, or there may be a more or less prolonged period of sexual inactivity between two successive phases. When there is but a single spawning period each year there is often a period of several months between the termination of one sexual phase and the beginning of the next.

The quohog (*Venus mercenaria*) may be taken as an example of consecutive sexuality. In this species, as determined by Loosanoff (1937), nearly all individuals experience a juvenile functional male phase when only a few months of age and only a small fraction of the definitive size. Following this initial male phase the sexes are with few exceptions strictly either male or female, with approximately equal numbers of each sex. There is no indication of a further change of sexuality. The primary, juvenile gonads are invariably more or less distinctly ambisexual, forming a graded series from predominantly male to predominantly female, although about 98 per cent of all individuals are protandric. The remaining 2 per cent are proterogynic. The adults are thus dioecious, following (with few exceptions) a more or less aborted primary male phase.

The sexual conditions in different individuals of this species may be schematized as follows:

1. Juvenile true male phase (exceptional) ... Adult male (true male).
2. Juvenile ambisexual male phase ... Adult male.
3. Juvenile ambisexual male phase ... Adult female (protandric female).
4. Juvenile ambisexual male phase ... Adult hermaphrodite (exceptional).
5. Juvenile female phase (exceptional) ... Adult female.

This type of sexuality is also characteristic of the wood-boring mollusk *Bankia setacea*, although the protandric females may experience a second change of sexual phase if the length of life of the individual is sufficiently prolonged. Self-fertilization is sometimes possible in the juvenile phase of protandric females, due to the overlapping of male and female phases (Coe, 1941). The population contains a small proportion of true males as well as of juvenile females; in the latter the initial male phase is aborted or omitted.

Xylophaga dorsalis, another species of wood-boring pelecypod, is evidently protandric, for most of the smaller and younger individuals function as males and the larger as females (Pynchon, 1941). The change of sex is indicated not only by the hermaphroditic gonad but also by the appearance of the seminal vesicles, which are large in the male phase but diminish in size and eventually disappear in the female phase. This is one of the few pelecypods in which a specialized storage organ for the sperm has been found but there is no direct evidence that self-fertilization is possible.

3. *Rhythmical consecutive sexuality*

Some of the ambisexual species which are composed of individuals living long enough to undergo

several complete spawning periods experience an equal number of sexual phases. Such is the case with the larviparous oysters, *Ostrea edulis*, *O. lurida*, *O. equestris* and others. In all of these the initial phase is usually male, followed by a series of alternating female and male phases throughout life. The eggs are fertilized within the mantle cavity, usually with sperm which have been discharged into the water by other individuals in the vicinity. The fertilized eggs are carried through the gills to the pallial chamber of the parent, where they complete development to the adult form.

The European oyster (*Ostrea edulis*) is the best known example of this type of sexuality as the result of the extensive studies by Orton (1927, 1927a, 1933). In this species the initial stages of spermatogenesis are begun even before the ova of the female phase are set free from the gonad. Sperm formation then continues for a month or two. After the sperm have been discharged the production of ova for the following female phase is begun. This phase may become functional immediately or may be delayed until the following year, according to the season. As a general rule under favorable conditions each adult oyster completes one male phase and one female phase each year. Since some individuals function in the male phase early in the spawning season and change later to the female phase, while others have the reverse sequence of the sexual phases, the oyster population is provided with both sexual types during the entire reproductive season (Cole, 1941).

Orton (1927) found much variation in the proportion of the two types of sexual cells in the gonads of different individuals, with all gradations from "pure male" to "pure female." The "pure male" differs from the male-phase individual which has followed the female phase in lacking ovocytes in the gonad and in the profusion of sperm produced.

The Pacific coast oyster (*Ostrea lurida*) experiences a similar series of male and female phases. On the coast of Southern California those individuals which are hatched in early spring may sometimes have three phases of funtional sexuality during one calendar year. A brief male phase when the individual is 4 to 6 months of age is followed by a more lengthy female phase. The latter may be concluded in time for a second male phase in the autumn. Spermatogenesis is usually in progress before the larvae of the female phase have left the mantle cavity.

Individuals which are hatched in the summer or early autumn complete only one or two sexual phases in that calendar year. This individual variation in periodicity provides the population with individuals in both sexual phases at all times during the spawning season (Coe, 1932a, 1934). Two separate spawning periods, resulting in two broods of young, may sometimes occur during a single female phase. Hopkins (1936, 1937) also concluded that in certain years about half the adult oysters in the culture beds in Puget Sound produced two broods of young during the spawning season, while in other years only about three-fourths of the adults produced even a single brood.

In addition to those individuals with regularly alternating sexuality the population contains a small proportion of true males which retain the male phase indefinitely and perhaps throughout life. Furthermore, some of the primary male-phase individuals, the so-called ambisexual males, have a preponderance of ovocytes in the gonad and change to the female phase after a brief initial male phase. Others of the same age have relatively few and small ovocytes in the primary gonad and retain the male phase much longer. And finally, the primary male phase is occasionally aborted or omitted, the first really functional phase thereby becoming female.

The following scheme will illustrate the successive sexual phases of these different classes of individuals:

1. True male (exceptional) ... Second male phase ...

2. Ambisexual male phase ... First female phase ... Second male phase ... Second female phase ... Third male phase, etc.

3. Primary female phase (exceptional) ... First male phase ... Second female phase, etc.

Another species, *O. equestris*, with similar sexual phases, is found on the southeastern coast of the United States and on the shores of the Gulf of Mexico. Gutsell (1926) first called attention to its ambisexual nature.

Teredo navalis, one of the species of wood-boring mollusks, likewise has a closely similar sequence of sexual phases. The protandric nature of the sexual cycle and the distinctions between ambisexual males and true males were reported by Coe

(1933). The sexual rhythm from the primary male phase to the female phase, sometimes followed by a second sequence of male and female phases, was described the following year (Coe, 1934a), with an account of the histological changes involved. In a brief summary of the sexual conditions of this species (Coe, 1935) it was shown that in exceptional individuals the initial sexual phase is female. Confirmation of this sequence with additional data was published by Grave and Smith (1936). A statistical analysis of the sexual phases of 2987 individuals examined at various ages and seasons of the year was reported by Coe (1936) as additional proof of the sexual rhythm and the presence in the population of a small proportion of true males and of a still smaller proportion of proterogynic individuals. These conditions were further emphasized in a subsequent paper by Coe (1941). In a study of young individuals only, Grave (1942) concluded that the proportion of proterogynic individuals was greater than previous observations had indicated. The data presented, however, do not seem to justify such a conclusion.

The following scheme will indicate the probable successive sexual changes in such individuals as live long enough to experience what may be considered as the normal sequence of sexual phases. Mortality during the second phase is usually very high and few individuals reach the fourth (female) phase.

1. True male phase (exceptional) ... Second male phase ...
2. Ambisexual male phase ... First female phase ... Second male phase ... Second female phase (if length of life suffices).
3. Functional hermaphroditic phase (exceptional) ... Male or female phase ...
4. Female phase (exceptional) ... First male phase ... Second female phase ...
5. Female phase (exceptional) ... Second female phase (?)

4. *Alternative sexuality*

In the oviparous oysters and perhaps in some other pelecypods the adults function seasonally as separate sexes, although it is impossible to predict during one reproductive season the sexual phase which the individual will assume at the next.

This type of alternative sexuality is illustrated by the commercial oyster of the North Atlantic coast, *Ostrea virginica*. At the first spawning season there is a strong tendency toward protandry, more than 70 per cent of the young oysters in some localities functioning as males at that time (Coe, 1938). After the second spawning season the number of individuals in each sexual phase is approximately equal, with a tendency toward an excess of females among the older individuals (Needler, 1936).

The adult Japanese oyster (*O. gigas*) was proved by Amemiya (1929) to be subject to a change in sexuality in the interval between two spawning seasons. A corresponding condition was found by Needler (1932), Burkenroad (1937), and Galtsoff (1937, 1938) in *O. virginica*.

Galtsoff (1937, 1938), using marked adult oysters, found that 8 per cent of those functioning as males changed to the female phase the following year, while 13.1 per cent of the females similarly reversed their sex. In the second year 11.2 per cent of the males of the preceding year showed a change of sex and 12.1 per cent of the females changed to the male phase. The total number of sex reversals in the first year was 9.7 per cent and in the second year 11.5 per cent. Hence this process of reversing the sexual phase seemed to be limited to a minority of the experimental animals. Moreover, 69 per cent of those that changed the sexual phase in the first year reversed again the second year. Some of the males which had changed to the female phase spawned in male fashion in the early part of the season but as typical females later.

In *O. gigas*, however, the proportion of the adult population experiencing changes in sexuality is evidently much greater, for Amemiya (1929) concluded that 25 per cent of the females and 60 per cent of the males in his experiment reversed their sex during one winter.

Protandry and change of sexual phase has been found in other species of oviparous oysters. Roughley (1933) concluded that nearly all the young of *O. cucullata* (*commercialis*) spawn first as males, although there appeared to be 2.7 times as many females as males in the adult population. Needler (1936) found more than 3 times as many females as males in an old population of *O. virginica*.

The primary gonad of *O. virginica* usually contains the antecedent cells of both sexes. Its protandric nature frequently becomes manifest when very young by the rapid proliferation of the spermatogonia and the formation of few or many ovocytes (Coe, 1932, 1934, 1938). In Long Island

Sound the process of gametogenesis often begins in the autumn when the animal is only 3 to 4 months of age; it is interrupted at the approach of winter and resumed the following spring. The first spawning occurs at the age of about one year.

The gonads of the young oysters previous to sexual maturity show all gradations between those of the so-called true males in which no ovocytes can be detected and those which develop directly into ovaries. Approximately 1 per cent (61 of 6315) of these young oysters become functionally hermaphroditic at the first spawning season. Most of the others function strictly as males or females during the first spawning season, although an occasional individual may produce sperm during the early part of the season and ova a few weeks later (Coe, 1938).

In those young individuals that are to function as males during their first spawning season, such ovocytes as may be formed in the early primary gonad are cytolyzed during the progress of spermatogenesis. Female sexual differentiation may be direct, with little or no indication of protandry, but it is more often indirect. In the latter case the primary gonad is more or less distinctly ambisexual during the autumn but takes on the appearance of an ovary the following spring by the proliferation of ovogonia and the cytolysis of the spermatogenic cells.

"A subsequent change from female to male phase evidently results from the later activation of some of the descendants of the primary undifferentiated gonia into spermatognia. The propagation of such undifferentiated gonia may be continued year after year or even through a long lifetime, since some residual gonia always remain after spawning" (Coe, 1938). The process by which this occurs is more fully explained by Loosanoff (1942).

The following scheme shows the presumable sexual phases of this species of oyster, based on the assumption that only those in which the primary gonad is ambisexual experience a change of sex in the second and later years.

1. Primary gonad male ... Male phase (first year) ... True male ...
2. Primary gonad ambisexual ... Male phase (first year) ... Male or female phase ...
3. Primary gonad ambisexual ... Functional hermaphrodite (first year) exceptional ...
4. Primary gonad ambisexual ... Male phase (early portion of first year); female phase (later portion of first year) exceptional ...
5. Primary gonad ambisexual ... Male phase (first year) ... Female phase (second year) ... Male or female phase ...
6. Primary gonad ambisexual ... Female phase (first year) ... Female (or male?) phase ...
7. Primary gonad female ... Female phase (first year) ... True female ...

Immediately after each spawning period the residual differentiated sexual cells undergo phagocytosis and cytolysis, leaving only undifferentiated gonia in the collapsed gonadal follicles. The individual thereby returns to a condition similar to that of sexual immaturity. Within a few weeks however, the apparently undifferentiated gonia resume activity and they then show that they have, in reality, become uniformly differentiated into the cells characteristic of the one sexual phase or the other. It is not at present known to what extent, if any, environmental conditions determine whether this differentiation shall be in the male or female direction.

The percentage of females at the first spawning season varies with the locality and with the season. The females at this time average somewhat larger than males of the same age and the data obtained as to the sexuality of more than 6000 young oysters from various localities from Cape Cod to the Gulf of Mexico indicates that those conditions and situations most favorable for rapid growth have the largest proportion of females. Examination of the gonads of 4033 yearling oysters from Long Island Sound whose sex could be determined indicated that 3578 were in the juvenile male phase and 416 in the female phase, together with 39 which were evidently hermaphroditic. This is a ratio of 11.6 females to 100 males. Different samples varied from 3.34 to 25 (Coe, 1938).

There were in the same collections, however, 406 individuals which were at the time sexually undifferentiated. Since female sexual differentiation commonly occurs at a later period than male differentiation, it seems probable that a much larger proportion of the sexually undifferentiated young would have developed into females than was found among those which were already sexually differentiated at the time of examination. The proportion of females is always largest toward the end of the spawning season, due in part to the protandric nature of seasonal hermaphrodites but especially to the delayed differentiation of females.

If allowance be made for these conditions it seems safe to assume from the data given by Coe (1938) that the yearling population of oysters in

Long Island Sound consists in average years of approximately 20 individuals in the functional female phase to 100 in the male phase.

A sample of 751 yearlings from Delaware Bay had a ratio of 41.92 females to 100 males, while three samples from Beaufort, North Carolina, varied only from 37.09 to 48.84 females to 100 males.

Whether these differences may be due to differences in the hereditary characteristics of the populations in the localities mentioned or whether to responses to different nutritive and other environmental conditions, or to both, is not at present known.

Since there is usually found an equality in the ratio of the sexes or an excess of females after the second year, it is obvious that at least 25 per cent of the juvenile males in these localities must later function seasonally as females. It is not known whether any of the juvenile females later change to males. Nor is it known to what extent environmental conditions influence the sex differentiating mechanism.

B. UNISEXUALITY; DIOECISM; GONOCHORISM

The vast majority of pelecypods are believed to be strictly of separate sexes, except for an occasional hermaphrodite. Such was formerly the conclusion in regard to *Venus mercenaria* and *Ostrea virginica* until their juvenile sexual phases, as has already been explained, were discovered in recent years. Consequently it is now evident that both juveniles and adults must be examined in order to ascertain definitely the sexual conditions of a species.

This has now been done for *Volsella* (*Modiolus*) *demissus*, *Mya arenaria*, *Petricola pholadiformis*, *Barnea truncata*, *Mytilus californianus*, *M. edulis*, *Septifer bifurcatus*, *Donax gouldii* and *Anomia simplex* without findings evidence of ambisexuality except in the sexually undifferentiated young gonads and an occasional hermaphrodite. None of these species has a distinctly juvenile phase of sexuality in the localities in which the investigations were made. Males and females occur in approximately equal numbers.

DISCUSSION

The inquiry may now be raised as to the significance of the diversities of sexuality that have been mentioned. Is the sex-differentiating mechanism so labile that it responds to relatively slight environmental changes or are variable genetic combinations more directly responsible for the variability observed? The answer seems to be that both these factors are presumably operative in all cases, although the evidence as to the influence of the environment requires more direct experimental proof.

In general, it is evident that there is often an inherent tendency toward a change in functional sexuality at successive reproductive periods. This change may occur during the brief interval between two successive spawnings in one season, as in the larviparous oysters, in *Teredo* and in *Pecten*, or in successive seasons, as in the oviparous oysters. There may be a single change, affecting the primary male phase only, as in the consecutive sexuality of *Venus* and as is usual in *Bankia* or the changes may be numerous, as in the long-lived larviparous oysters.

Juvenile sexuality, or neoteny, as reported for *Venus* and oviparous oysters is of wide occurrence in both animals and plants, being characteristic of certain gastropods (as *Crepidula*), annelids (as *Ophryotrocha*), gephyreans (as *Bonellia*), echinoderms (as *Leptasterias*), nemerteans (as *Geonemertes*), and has been reported for crustaceans (*Pandalus*), fishes (*Sparus*), and amphibians (*Rana*). It is, of course, well known for the axolotyl. Some of these resemble the pelecypods mentioned in that the sexuality of certain individuals in the juvenile phase is opposite that of the adult. Both in the pelecypods and in the other groups mentioned the neotenous condition is often abortive, leading to the cytolysis of such gametes as may be partially or fully formed; hence spawning may not occur in the juvenile phase.

Particularly noteworthy is the variability in the sexuality of different individuals of the same species and in some cases in a single individual at different periods of life. This variability resembles in some respects the color patterns of certain mammals or of certain plants. Both are evidently the visible manifestations of various combinations of multiple modifying hereditary factors.

In the functionally hermaphroditic species, as *Pecten*, for example, the relative extent of the spermatic and ovarian tissues in the gonad is highly variable. Some individuals closely approach a unisexual condition, particularly a female condition, with only a very small amount of spermatic tissue or none at all. But occasionally the relations are reversed. Furthermore the extent of protandry or of proterogyny varies greatly in different members of a single population.

The importance of environmental influences in modifying these characteristics has not been satisfactorily shown experimentally for the pelecypods, although Amemiya (1935) found that groups of Japanese oysters having portions of their gills removed showed a larger percentage of males the following season than similar groups with uninjured gills. Awati and Rai (1931) also concluded that the disturbance in the nutrition of the Bombay oyster caused by the commensal crab *Pinnotheres* increased the proportion of males and Rosenwald (1926) found that the gastropod *Limax* became protandric or proterogynic according to the environmental conditions, particularly the amount of moisture. It was mentioned that the Virginia oyster has a larger proportion of females in the yearling population in those years and in those localities most favorable for rapid growth (Coe, 1936, 1938). At this age the functional females are of larger average size than those individuals that are functioning as males. Hence it seems quite possible that temperature and nutritive conditions within the body may influence the proliferation of one rather than the other of the alternative types of sexual cells in the early ambisexual gonad. Such influences are well authenticated among nematodes, annelids, amphibians and plants.

In several groups of animals, both invertebrates and vertebrates, as well as in some plants, there exist local races with differing hereditary types of sexuality. Such races are reported by Bloomer (1939) in the fresh-water pelecypod *Anodonta cygnea*, and have been thought to exist in the Virginia oyster (Coe, 1936, 1938). Additional information, particularly of an experimental nature, will presumably reveal them in many other species.

CONCLUSION

It may be concluded then that the pelecypods as a group are predominantly of separate sexes. Among the relatively few hermaphroditic species four intergrading types of ambisexuality are recognized: functional ambisexuality (functional hermaphroditism), consecutive sexuality, rhythmical consecutive sexuality and alternative sexuality. Some of the hermaphroditic species are characterized by multiple modifying hereditary sex factors which may produce all grades of ambisexuality from true males to true females.

There are also various hereditary physiological time factors which control the periodicities of the alternative sexual phases. The ambisexual species show a general tendency toward a rhythmical series of alternating male and female phases, of which the initial sexual phase is more frequently male. Some of the species appear to be composed of local races with differing sexual tendencies and these tendencies become manifest in differing degrees according to the environmental conditions.

The sexual conditions described on the foregoing pages are not peculiar to the pelecypods but have their parallels in other groups of organisms, both animals and plants. Even in the sponges there are species with incompletely separated sexes, some individuals functioning for a time as males and others as females, while the later formation of eggs in predominantly male individuals suggests a general tendency toward protandry (Fincher, 1940). Such is also the case with certain planarians, gephyreans, nematodes, annelids, nudibranchs, gastropods, echinoderms, crustaceans, and fishes. In some of these, as has been mentioned for *Venus*, the fully mature individuals are strictly of separate sexes, although nearly all the young first function as males. The genetic males (true males) continue to function as such throughout life, while the genetic females (hermaphroditic males, or protandric females) function as males when young and as females thereafter.

There is no direct proof of phenotypic sex determination in the pelecypods, although as a general rule in cases of alternative sexuality the male phase is often indicative of immaturity and unfavorable environmental influences, while the female phase is more often associated with optimum physiological conditions. This is in harmony with the evidence from other groups of animals and plants.

All these manifestations of sexuality are consistent with the view that the prospective sexuality of the individual is dependent upon the quantitative balance of the male as opposed to the female factors in the hereditary mechanism. They may all be referred to the homozygosity or heterozygosity of the primary sex factors, with their associated modifying factors for the activation or suppression of either the male- or female-determining components at certain stages of development or in harmony with different degrees of physiological maturity. They are also responsive to environmental conditions both within and without the body of the organism.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to B. H. Willier, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *Department of Biology, Homewood Campus, The Johns Hopkins University, Baltimore, Maryland, U. S. A.*

BRIEF NOTICES

EVOLUTION

PLIOCENE VERTEBRATES FROM BIG SPRING CANYON, SOUTH DAKOTA. *University of California Publications. Bulletin of the Department of Geological Series, Volume 26, No. 4.*

By Joseph Tracy Gregory. University of California Press, Berkeley. $2.00. 10½ x 6¾; 307–446 + 3 plates; 1942 (paper).

This detailed report on fossil forms from South Dakota makes a valuable addition to the fine records that we already have from northwestern United States. Big Spring Canyon is on the edge of the sand hills of Little White River, not far from the Nebraska boundary line. Only a few associated skeletons were found in the deposit. Mostly the bones from many animals were heaped at random in small pockets in the bottoms of the old stream channels. The small amount of material in the deposit indicates a relatively short period of accumulation as well as a small drainage area. "... the broken nature of the material, the variety of fauna present, and the excess of jaws, skull elements, and foot bones over the number of vertebrae and ribs, suggest that the animals died near the stream, the skeletons being washed into its channel during floods." The relatively large number of immature individuals in the collection, especially camels and antelopes, indicates the possible effect of prolonged drought or severe winter conditions.

Gregory states that the fauna represented in the Big Spring Canyon (29 mammalian genera) is the "most varied Lower Pliocene mammalian assemblage known at the present time from North America." There is evidence that the entire fauna was contemporaneous. "Ecologically the fauna combines aquatic and riparian elements with a dominant group of plains animals, such as horses with hypsodont cheek teeth, antelopes, camels and carnivores." Included in the text are tables of bone measurements and 51 figures. Two plates show cranium and jaw bones. A lengthy bibliography concludes the report.

GENETICS

AN INTRODUCTION TO BREEDING FARM ANIMALS.

By Laurence M. Winters. John Wiley and Sons, Inc., New York; Chapman and Hall, London. $2.00. 8 x 5⅜; x + 250; 1942.

With the increase in purposeful and directive methods of animal breeding, there has been a demand on the breeder's part for some scientific background of genetics and reproductive physiology. An attempt is made to supply this information by the author. The process of reproduction and the basic principles of genetics are presented in an elementary way for non-biologically trained readers. Neither of these topics is one for simple elucidation, of which fact the writer is well aware, and to know just how far to carry such information is always a source of difficulty.

Grading, inbreeding, crossbreeding, artificial insemination, fertility, and management are some of the other phases of the subject that are discussed.

GENERAL BIOLOGY

MAN AND THE BIOLOGICAL WORLD.

By J. Speed Rogers, Theodore H. Hubbell and C. Francis Byers. Mcgraw-Hill Book Company, New York and London. $3.50. 9 x 6; x + 607; 1942.

This new textbook is intended for a survey course in the biological sciences. As such it presents a surprisingly large amount of material with stress fortunately laid on the data and reasoning on which biological principles are based. As a matter of fact it should prove quite

usable as a text for an introductory course for students planning to continue work in biology.

The book is divided into four main parts entitled: The individual organism; The continuity of the race; The changing generations. The evolution of life in time and space; and The economic and social interrelationships of organisms. The first part is concerned primarily with an account of the structure and physiology of the human body and of a flowering plant. The structure of other animal and plant groups is touched very briefly in a final chapter.

The second part is concerned with reproduction, embryonic development, and inheritance. Reproduction and inheritance are treated quite fully, including a chapter on inheritance in man. On the other hand development in animals is dismissed with ten pages at the end of one chapter. To the reviewer, this appears an unnecessary abbreviation of an important subject in view of the fact that space was found for five chapters on genetics and eleven on evolution.

The third part is concerned with evolution. Evidence for evolution is presented, and the major theories of the mechanism of evolution are reviewed. The devotion of a separate chapter to each of the geologic eras seems excessive in view of the very small amount of space devoted to present day forms.

The fourth part deals with the effects of both the physical and biotic environment upon organisms. Appendices giving a survey of the kinds of organisms, a list of books for outside reading, and a glossary of terms are included, and there is an index.

In general, this book is well done. The writing is usually clear, and there are many excellent photographs and diagrams. It might be said, however, that the authors have on several occasions introduced concepts without adequate explanations. It would be better to omit these concepts entirely than to treat them so briefly that the student could get only the vaguest idea of their meaning.

A General Science Workbook.

By Douglass Elliott Weidner. The Jaques Cattell Press, Lancaster. $1.00. 10¼ x 7¼; 216; 1942 (paper).

Convinced that science is related to the everyday life of the individual and is important in the school program, the author of this workbook has endeavored to present exercises that are interesting and thought-provoking, and that will develop skill in scientific habits, and in the ability to compare and to generalize.

The organization of the book is based on the unit plan of study. It is designed to secure the interest of the pupil by challenging his thinking. It provides for individual differences in learning—the student is permitted to work at his own speed, as it were. Provision has also been made for extra reading. The subject-matter is taken up in the following order: the solar system, time, air, weather and climate, water, heat, machines, magnetism and electricity, sound, light, transportation, and biology.

It is unfortunate that more attention is not given to plants and animals, and, in the opinion of the present reviewer, this is a decided weakness of the manual. Lists of references for reading are given at the end of each unit. The numerous illustrations are simple and clear-cut and of obvious real value to the beginning student of science. Space is provided for writing the answers to the numerous questions asked, so that no additional notebook is necessary.

Oceanographic Observations on the "E. W. Scripps" Cruises of 1938. *Records of Observations, Scripps Institution of Oceanography, Volume I, No. 1. By H. U. Sverdrup and the Staff of the Scripps Institution of Oceanography. University of California Press, Berkeley and Los Angeles.* 75 cents. 11 x 8½; 64 + 39 charts; 1942 (paper).

Results of the five cruises of the *E. W. Scripps* during 1938 off the coast of southern California are presented by the various contributors to this volume. Following the introduction by Sverdrup, there is a nautical description of the ship and its fittings by E. G. Moberg and J. Lyman. Preliminary discussions on the results in physical oceanography, on the diatoms, and on the zooplankton, are given by R. H. Fleming, W. E. Allen, and M. W. Johnson respectively. The remaining half of the report is devoted to tables of oceanographic observations, and include temperature, salinity, and oxygen determinations, values of phosphate-phosphorus content, and counts of plankton diatoms.

HUMAN BIOLOGY

Climate Makes the Man.

By Clarence A. Mills. Harper and Brothers, New York and London. $3.00. 8½ x 5¾; vi + 320; 1942.

The awareness of a connection between human welfare and the solar system is older than recorded history, and reverence for the sun and its satellites was carried to great extremes in early civilizations. For many centuries people believed that outside forces exerted potent influences over human affairs and the astrologer's advice was always in demand. Without subscribing to the unfounded tenets of astrology, we now have "a scientifically discovered and direct chain of influences meshing our daily lives into the larger forces of our own solar universe." The planets in their shifting positions around the sun cause the sun spots to wax and wane

resulting in variations in solar radiation to the earth and changes in temperature and storminess. We know beyond doubt that these weather changes, both short-cycle and over longer periods, profoundly influence our body functioning.

Mills has been interested for many years in the effects of climate and weather upon the body functions of man and other animals. He has tested many of his hypotheses on various animals in the laboratory where almost any existing climatic condition can be readily and easily duplicated. In this very fascinating and readable book, he gives us the results of his rather extensive researches both in the laboratory and in the field, which show how the climates we live in by choice or chance influence very markedly our physiology.

The book is divided into three parts: the first part shows how climatic forces affect people in the tropics. Such myths as early physical and sexual maturity among tropical inhabitants are clearly dispelled. In a chapter on Vitamins and climate many interesting points are brought out concerning the differences due to climate in the daily needs of various vitamins. For example, a person living in the tropics needs more of the B vitamins per day than one living in temperate regions. According to this, there is good reason for the use of highly seasoned foods in the tropics, since most spices are ground from seeds rich in B vitamins. The second part of the book emphasizes the driving force and health toll of energizing cooler climates.

> Temperate zone nations are leaders in world affairs. Their peoples, activated by cool climates, have had the energy to build great power plants, sky scrapers, dams, bridges and a legion of impressive monuments of human initiative. . . . A life full of activity and stress is temperate-zone man's unconscious response to climatic urging; he himself has little choice in the matter.

In this section of the book the author discusses the varying effects of drugs and stimulants such as caffeine, nicotine, alcohol, etc., under different climatic conditions; the relation of climate and weather to tuberculosis, arteriosclerosis, sinusitis, cancer and various other ills, and the advisability of planned conception of children in winter and spring, the seasons of optimal health and vigor.

The final third part of the book deals with the larger effects of climate and weather on mankind and his progress in general. These chapters are filled with stimulating information and scientific conjecture. The author's theories with regard to the future of the world in relation to climate and the general rising temperature of the earth itself are worth reading.

It should perhaps be pointed out that the author, in this book, is dealing primarily with the relation of climate to man and makes no mention of a variety of other fields such as ecology, soil content, race, etc. which also have a relation to the history of man and to his future.

EDWARD SYLVESTER MORSE. *A Biography.* *By Dorothy G. Wayman. Harvard University Press, Cambridge.* $4.50. 8¾ x 5¾; xvi + 457; 1942.

When the famous entomologist, L. O. Howard, in his biographical memoir of Morse for the National Academy of Sciences, prophetically remarked, "There should be a book about Morse. One will be written some day," he was but voicing the hope of all who had been fortunate enough to know Morse, however slightly, and of the many others who, knowing only his writings, had sensed that behind this admirable work stood a colorful and interesting personality. Now, eighteen years after Morse's death, Mrs. Wayman admirably fulfills Dr. Howard's prophecy and most satisfactorily meets this long-felt need with the most successful and delightful biography it has been the good fortune of this reviewer to read in years. As the factual basis for her book, Mrs. Wayman must have carried on a tremendous amount of painstaking and discerning research through extensive source material, including Morse's diary, records, journals, and voluminous correspondence, and privately printed or manuscript notes and memoirs generously furnished by relatives and friends and by the institutions and societies with which he was connected. It is clear that she spared no pains, also, in her thorough and discriminating reading of his many published works in various fields from books and major contributions to lectures, occasional papers, and brief notes. Her thoroughness is still further evidenced by her trip to Japan in 1939 to secure first-hand information regarding Morse's work there and his stimulating influence on the development of biology and science in that country.

More than this, she has, with sympathetic understanding, revealed Morse as a personality and as a man. For those of us who knew him, he lives again in these pages, the charm of his enthusiasm, the warm heart of his friendship, the intensity of his diverse interests bringing back his infectious boyish eagerness, his delightful quirks, his facile sketches, his kindling enthusiasm. For those who knew only his books or his scientific papers, this biography will be a revelation, for in it they will find the motivation for the intense interests which found their ultimate fruition in his writings, while the vividness of his personality, his spontaneity and enthusiasm, his drive and energy, his boyish zest and vitality reveal why, throughout his life, he was such a quickening and inspiring influence upon all who came in contact with him.

In this book his accomplishments are well portrayed, his fundamental and continuing interest and work in shells, his major contribution to biology in correctly placing the Brachiopods in relation to the Annelids rather than to the Molluscs, his great service to science through championing the concept of evolution despite the opposition of Louis Agassiz and of the church, and, by the vividness and effectiveness of his lectures, ex-

plaining its principles so clearly that they were grasped and accepted by the layman. His success as a lecturer and teacher is well brought out and exemplified by the progressive and advanced approach of his textbook and the justifiable popularity of his lectures on any subject. Especially effective is Mrs. Wayman's portrayal of Morse's authoritative work on Japanese pottery from his early intense scientific concentration in this field in Japan under the able tutelage of Noritane Ninagawa to his indefatigable and discriminating accumulation of his famous collection, his final production of one of the most effective, interpretive, and learned catalogues in the field of ceramics, and his subsequent authoritative, expert aid to famous galleries such as the Freer and other museums in this country and in Europe before and after his collection was finally installed in the Boston Museum of Fine Arts as the finest collection of its sort in the world. Here also is described his pioneer work on arrow release, his discerning analysis of the several types used by different peoples as developmental improvements on each other and as ethnological indices of the racial sources of the two major types, Mongolian and Mediterranean, that gave supremacy to the peoples which developed them. His 45 years of work as Director of the Peabody Museum in Salem are well covered, the unusual effectiveness of his organization and display of the collections there being recognized not only as a great achievement in itself, but also as a strong influence on the improvement in museum technique notable during recent decades.

Yet a man's achievements, however diverse, important, and influential, are but part of himself, and this biography goes much further than most in that it interprets Morse's accomplishments in the light of his personality and his spirit. Indeed, it shows clearly that his personality was the key to his accomplishments, for it reveals that, in addition to his extraordinary keenness of observation and his unerring ability to depict in rapid, accurate sketches the essential character of objects scientific or artistic, he had the quality of intense concentration on subjects interesting him to the exclusion of other things, yet the ability to carry along several such active, constructive, dynamic interests, shifting from one to the other at high speed with effective intensity. It shows Morse to have been an utterly natural, wholly sincere, forthright and honest man with great capacities for friendship, winning the liking and ready cooperation of all with whom he came in contact, from children, students, and casual acquaintances to leading scientists and outstanding figures in many fields.

It would be easy in the biography of such a man to lapse into sentimentality, and the author is to be complimented on a human, revealing, and delightful book free from any such flaw. His shortcomings, which were many, are not glossed over; his good qualities, which were more, are not exaggerated. The book is free from any taint of the modern, deplorably popular attempts at amateur psycho-analysis, and the early influence of his stern, bigoted father and of his understanding and gracious mother are here shown with straightforward commonsense, as are his later relationships with Agassiz and other associates, his attitude toward his wife and children, and his associations with his secretary, Marietta Brooks, and with the many students and colleagues who worked with him in Japan, in Europe, and in this country.

It is a high tribute to the author's accuracy and care that, in a book so packed with technical terms and references in several scientific fields, the only obvious error is the misspelling of the anatomical term astragalus, which, incidentally, may stem from Morse's highly original spelling, since the first error in the form of "astralgus" occurs in a quotation from his own journal.

Of special interest at the present time is the illuminating insight into the thought and character of the Japanese of the period from 1877 to 1879 when Morse taught at the University of Tokyo, and from May to November, 1882, when he made his last trip to collect pottery. To recent analyses of the Japanese there could be no greater contrast than Morse's observations in his journals, his letters, and his two books, *Japan Day by Day* and *Japanese Homes*. After seeing the Japanese of that time through Morse's observant eyes and honest mind, one can appreciate that the change which has come over that country since Morse's time, while reaching much the same end point as the more recent changes in Germany, is the more regrettable in that Japan in those earlier days had potentialities for great contributions to science, art, and peaceful progress.

It is, perhaps, unfortunate that the author did not list Morse's many books, publications, and other contributions in an appendix, but as most of these are listed in imposing array in the brief biographical necrologies which have appeared in the transactions of various scientific societies in which he had been a leading member, and as they are discussed here, this lack is no real detriment. Here something much more valuable is given, the circumstances that led to his starting on a line of work, and the dynamic, intense effort that carried the work through even under difficulties. Here one can see the qualities whereby his work won for him the esteem and admiration of scientists on three continents; one can appreciate why Morse, who had paid tuition to no college and had had but the most scanty and fragmentary elementary schooling, was a leading member of the most important scientific societies in this country and elsewhere, was chosen as President of the American Association for the Advancement of Science, and was the recipient of four honorary degrees from American colleges and universities.

After reading this book, one realizes that even in scientific work, the priceless additional ingredients are

the personal ones of eager zest and vital enthusiasm, and that because of these qualities Morse was a catalyst stimulating and arousing others, even in unrelated fields, so that the influence of his work, and even more of his personality, still lives.

IN THE HIGH YEMEN.

By Hugh Scott. John Murray, London. 18s. 8¾ x 5⅞; xix + 260; 1942.

In 1937–1938 the Natural History section of the British Museum sent two of its members, Hugh Scott and Everard B. Britton, to South-West Arabia for the purpose of collecting plants, insects, and other small animals in the higher mountains of this region, particularly in the Yemen. South-West Arabia is of peculiar interest to the naturalist. It has had an interesting geological history. Along the southern half of the Arabian shore of the Red Sea lies a great mass of mountains, whose tablelands average 8,000 feet above sea level, while the higher peaks rise to an elevation of 12,000, or more, feet. The low coastal strip is barren, and beyond the mountains are deserts and steppes. Due to the saturated winds of the south-west monsoon, blowing in from the Indian Ocean during the summer months, the Yemen mountains receive a heavy and regular rainfall, and conditions are favorable for the fauna and flora of temperate regions. Tropical (largely African) forms are found on the hot lowlands of the coast and in the deep valleys, while in between the two regions both tropical and temperate species mingle. The importance of this region biologically is due to the fact that its fauna and flora "link on to and overlap those of three great biogeographical regions—the Northern or Palaearctic, the Oriental, and the Ethiopian or Tropical Africa."

Scott and Britton first spent some time in the Western Division of the Aden Protectorate, which is under British control, where they were able to collect from areas comparable to areas in the Yemen which they were later prohibited from visiting. At the present time foreigners, and particularly those wishing to explore the country, are not welcome in the Yemen—"the Kingdom and Imamate of the Yemen is a closed mysterious country, its ruler is a sacred personage, holder of a centuries-old office, combining in himself spiritual and temporal sovereignity." A first part of the technical reports of the Expedition has already appeared—*British Museum (Natural History) Expedition to South-West Arabia, 1937–38, Vol. I, Nos. 1–8*—and is reviewed in the present issue of this Journal in the section of zoological literature. Other parts will appear later as the great mass of collected material is worked up.

High in the Yemen, the story of the expedition, tells of the many interesting things that Scott and Britton, seasoned explorers and collectors, observed and recorded concerning the natural history of the country, the country itself, and the people. Scott has the happy faculty of imparting to his readers his own interest in his daily experiences, whether it be the exploration of a cave, the finding of tiny flies (a new species of Phoridae) which prefer to ride on the back of a large black millipede although quite capable of flying, the journey to San'a, capital of the Yemen, or his interview with the Imam, ruler of the country. He gives interesting descriptions of the people, whom he found generally friendly, their customs, their dress, and their fascinating dances. The latter part of the book is devoted to the past history of the peoples of South-West Arabia, both before and after the coming of Islam.

Scott and Britton, in addition to their numerous duties as collectors—around 27,000 insects were brought back to England, as well as other forms of animal life and many plant specimens—found time to take numerous photographs. Over one hundred of these are included in the present volume and form a fine pictorial record of the country districts, the mountains, the villages, the cities, and the inhabitants. A bibliography of books and articles of a general nature on this part of Arabia, and a detailed index complete the volume.

A first class travel-book, also important as a source of information concerning a country and a people on the edge of the war zone.

THE TEACHER OF NATIONS. *Addresses and Essays in Commemoration of the Visit to England of the great Czech Educationalist Jan Amos Komenský Comenius 1641–1941.*

By Eduard Beneš and Others. Edited by Joseph Needham, with a Chronological Table Showing the Events in the Life of Comenius by R. Fitzgibbon Young and a Select Bibliography of the Works of Comenius by Anna Heyberger (translated by Corinne Barham). Cambridge, at the University Press. $1.75. 8½ x 5½; iv + 99; 1942.

The subject of this book is one to whom history has been somewhat unkind. It is possible to be well educated without ever having heard of Jan Amos Komenský, or knowing that the leading seventeenth century figure in the field of education was a Czech. Yet not only is this the case; it is also true that Comenius (he is better known by the Latinized form of his name) anticipated the educational reforms later championed by Pestalozzi, refused to sanction any discrimination based on racial, sexual, or social grounds in the university which he hoped to establish in England and actually turned down a call to the presidency of Harvard, if we are to credit a popular tradition.

In one of these essays in the symposium, J. D. Bernal,

of the University of London, states that Comenius represented the link between mediaeval and modern knowledge far more than Bacon did, though chronologically Bacon came first. His visit to England in 1641 was for the purpose of founding a university, which in his writings is referred to sometimes as "The Philosophical College," sometimes as "The College of Light," but more generally "The Invisible College." The latter name may indicate Rosicrucian influence—it has been much debated.

Comenius' failure to establish his college, according to J. L. Paton, of University College of Newfoundland, was lack of competent faculty. There were teachers in plenty, but none capable of grasping Comenius' ideas. Education in the seventeenth century consisted chiefly of syntactical Latin. The pupils were not trained to speak Latin, or to read it, or to understand it, but if they were diligent, they could learn to recite the rules and the exceptions. Comenius did not wish to abandon the use of Latin in education, but he wished to substitute contemporary scientific Latin for the literary Latin so popular at the time, and he wished to have a vernacular school to precede the Latin School. All told, his educational ideas seem to have much in common with those of William Penn, expounded in his *Some Fruits of Solitude* and the reader is likely to wonder if Penn was influenced during his student days by Comenius.

Perhaps the most interesting essays in the collection are those by Eduard Beneš and Ernest Barker, for they dwell on the historical background, and throw light on that shadowy figure who preceded Comenius by two centuries—Peter Chelčicky, a Tolstoyan before Tolstoi, a disciple of John Hus, the founder of the Jednoka Bratrska, or Unitas Fratrum, the group with which the name of Zinzendorf is indissolubly linked.

The work is not indexed, but it has a good bibliography. It has a frontispiece—the title page from one of Comenius' works, published at Amsterdam in 1657—and a reproduction of a picture of Chelsea College, which he planned to take over, but which instead became the Military Pensioners' Hospital.

HADDON THE HEAD HUNTER. *A Short Sketch of the Life of A. C. Haddon.*

By A. Hingston Quiggin. Cambridge: at the University Press. $1.75. 7⅞ x 5; xii + 169; 1942.

In the rapid rise of the young science of anthropology Haddon has played a leading part and has been of the greatest help in that arduous struggle toward winning recognition for a Science of Man. Haddon was born in London in 1855 and was appointed Professor of Zoology at Dublin in 1880. In 1888 he went to Torres Straits as marine biologist, but spent all his spare time studying the aborigines and his meagre means acquiring ethnological material, his interests having shifted from the lower to the highest of all animals. In 1895 he was appointed lecturer in physical anthropology at Cambridge and in 1900 there was created for him after much opposition a lectureship in ethnology with a stipend of 50 pounds a year! He referred to this difficult period in a speech at his 70th birthday by stating: "Our university sometimes seems to behave more like the traditional step-mother than like Alma Mater—the Nourishing Mother." Haddon died in 1940, honored by scientific societies from all parts of the civilized world and having amassed a bibliography to his name containing over 600 entries. His most widely-known works are the *Races of Man* and *History of Anthropology*. Haddon was a stimulating lecturer and prodigious worker to the end of his days. His sense of fairness as well as of humor is best shown by the following quotation from his course in craniometry: "Where the female differs from the male it is in being more infantile," and after a pause "where the male differs from the female it is in being more ape-like and senile."

This biography is charmingly written, revealing with much devotion and detail the development of a rare personality and of a scholar with unusual perseverance and great vision against a background of profound academic indifference and innumerable discouragements. Anthropology is still the "Cinderella of the sciences" at many universities and needs more leaders with Haddon's admirable qualities.

It is to be regretted that the author has omitted any reference to Haddon's relations with his contemporary anthropological colleagues at home and abroad. Haddon did not live and work in such anthropological isolation as would appear from this otherwise most welcome biography.

GROUP DIFFERENCES IN URBAN FERTILITY. *A Study Derived from the National Health Survey.*

By Clyde V. Kiser. Williams and Wilkins Company, Baltimore. $2.50. 8¼ x 5½; ix + 284; 1942.

The future of human populations as related to present trends in births and deaths has been the center of one of the most active fields of scientific investigation for the past three decades. The data for the present study of human fertility were collected in conjunction with a National Health Survey conducted in 1935–36 by the United States Public Health Service. Although the data are not as perfect as even the author would have desired, they have been carefully analyzed and prudently interpreted, and as such, they make a worthy contribution to this absorbing phase of human endeavor.

Significant among the broad facts revealed by the study is that of a striking trend toward equalization of fertility rates among the various strata of socio-economic and educational levels in the urban popula-

tions of the United States. Specifically, it was found that the native white women have a higher rate of fertility than either the foreign-born white or the colored elements of our city groups. The passing of most of the foreign-born women out of the highly reproductive age group, and the lack of young immigrants to augment their numbers have been responsible for the abrupt drop in fertility of the foreign-born whites. Illegitimacy and reproductive wastage are considered the important factors relating to low fertility among urban colored women. The apparent rise in fertility among native white women in the upper socio-economic and educational brackets is largely due to a slight reduction in fertility among the lower groups, which, in turn, is largely due to greater contraceptive practice. The position is taken that the present picture of fertility in urban America is typical for a nation immediately following the impact of concerted contraceptive effort. The implication is that with the advent of contraceptive knowledge among professional groups, the fertility of these groups is abruptly reduced, and that as the knowledge is disseminated to the lower brackets of society, the group differences in fertility become progressively equalized.

The weaknesses of the data are not minimized by the author, but rather are pointed out as guide posts for the future investigator of the subject to use in designing better organized studies of specific phases of human fertility. One obvious and admitted weakness of the study is that relating to reproductive wastage. This is to be expected, since the data on still-births and abortions were collected only incidentally to female morbidity, and since many of the field tabulations were made by non-medical, male enumerators, to whom the subjects were reticent about revealing the details of their pregnancy wastage records.

The work is well supplied with tabular and illustrative material. Appendix tables showing the gross aspects of the numerical data, a bibliography of some 60 titles, and an index conclude the volume.

STONE MEN OF MALEKULA. *The Small Island of Vao. By John Layard. Chatto and Windus, London.* 50s. net. 10 x 6⅝; xxiii + 816; 1942.

As the title suggests, Layard deals mainly with one aspect of New Hebrides culture in Vao, one of the small islands east of Malekula: an ancestor cult, centered around stone monuments. During a complicated ritual, the completion of which takes 15 years, stone platforms, dolmens and monoliths are erected, hundreds of boars with artificially deformed tusks (replacing human victims) are sacrificed, dances executed, etc. The male participants of the rite are reborn and advance thus in a public graded society. The highest ranks become equal to the ancestor spirits and thus able to reach after death a kind of paradise in a volcano of the neighboring island of Ambrim instead of being devoured by the spirit Le-hev-hev. The author treats in great detail the different material and spiritual elements of this Maki cult: stone and wooden images, wooden gongs, dances, mythological implications, the pig husbandry and currency, social function and comparative history of the rite.

Layard also devotes great attention to the classificatory family system in Vao, a strange blending of old matrilineal and overt patrilineal elements. He deals with initiation and mortuary rites and contributes some excellent chapters on warfare, cannibalism and human sacrifice, canoes and sand designs.

The book is based on material collected in 1914–1915 when Layard went to Melanesia with the late W. H. R. Rivers. He incorporates in his book almost entirely the observations of the late Father Godefroy who lived in Vao about 15 years after Layard. This incorporation is a great advantage, not only because Godefroy was a keen observer and good writer, but because changes which occurred meanwhile can thus be registered and analyzed. As Layard is a pupil of Rivers and C. G. Jung, it is not surprising that he is sometimes inclined towards rather controversial "historical" and psychological speculations. His rather one-sided interests are perhaps also partly responsible for the fact that, in spite of the tremendous space devoted to this subculture, one unfortunately does not gain from the book a real impression of Vao culture as an entity. We are of course particularly sensitive to this shortcoming in a field such as Melanesia where the late B. Malinowski and his followers (R. Fortune, M. Mead, etc.) have done most of their work, which is outstanding just in giving a real picture of society as a whole. In every respect it would perhaps have been advantageous if Layard had not disregarded so completely this work, although it developed only after 1914.

The book will be, in spite of these objections, of great utility to all those interested in Melanesian culture, family systems, or the monolith problem.

RACE, REASON AND RUBBISH. *A Primer of Race Biology. By Gunnar Dahlberg. Translated from the Swedish by Lancelot Hogben. Columbia University Press, New York; Allen and Unwin, Ltd., London.* $2.25. 7½ x 5; 240; 1942.

In the author's preface written one month before the outbreak of World War II we read:

It must have been extremely awkward for astronomers and physicists when laymen eagerly debated the theories of Copernicus and when his opinions were condemned by the Roman Catholic Church in the sixteenth century. The frantic discussion which followed the

announcement of Darwin's doctrine now seems quite remarkable, and when a legal action is taken against a schoolmaster in a small American town because he has given instruction about evolution it raises a solitary smile. Time will come when public discussions, such as those we now have about race, will be looked upon as equally queer.

This time has not come as yet and three years after these lines have been written one comes to wonder whether we have lately moved closer to it. However, it seems certain that the great international conflict has aroused, in the democratic countries at least, an interest in the problem which creates a demarcation line between the two ideological camps. Dahlberg's book will be welcomed by all laymen who are looking for an objective, adequate, and scientific treatment of the racial problem.

Since "one cannot discuss race problems without proper knowledge of the laws of heredity", the first five chapters of the book (1. Fundamental mechanisms of inheritance; 2. Independent assortment and linkage of genes; 3. Polymeric characters, dihybrid inheritance and mutation; 4. Sex determination and sex-linkage; 5. Environment and gene exhibition) provide the reader with the required elements of genetics. Chapter 6 (Principle of random mating) is a discussion of the genetic equilibrium, and the following four chapters (7. Selection; 8. Inbreeding and cousin marriage; 9. Assortative mating; 10. The isolate effect) deal with the different causes of deviation from the theoretical equilibrium. This second part of the book is based mainly on facts of human genetics and is really a discussion of the genetic structure of human populations. It thus gradually leads up to the discussion of the notion of Race (Chapter 11) and of the Jewish question in the last, the 12th chapter.

The author's intent was to present a "succinct popular exposition" of human genetics. In this he has brilliantly succeeded without running into the common drawback of popular books— that of giving an oversimplified picture of the problems involved and of their solutions. The treatment remains strictly scientific in spite of its simplicity and strictly objective in spite of the author's own sense of social justice which transpires in sentences such as: "The negro comes into the world with a skin which darkens quickly after birth, and with a brain which soon blackens before the realisation that he must abandon all hope. We do not know what might happen if negroes were treated as social equals with access to the same privileges as white men."

MAN'S MOST DANGEROUS MYTH: *The Fallacy of Race. By M. F. Ashley Montagu, with a foreword by Aldous Huxley. Columbia University Press, New York.* $2.25. 7¾ x 5¼; vii + 216; 1942.

This work constitutes the most vigorous arraignment and condemnation of race prejudice that the present reviewer has ever come across. In it Montagu thoroughly debunks the pretensions of those who would deport the Negro-Americans to Africa, the Mongolo-Americans to Asia, and refuse to give America back to the Amerind. Yet the author says little that is new. He merely says it more emphatically and convincingly.

Genetically, man consists of a great number of characteristics which assume forms determined in the chromosomes. In the course of time certain combinations of these characteristics prevail over others in certain localities, while in other localities certain other combinations may prevail. Whether in the course of time different combinations may give rise to geminate species is irrelevant; the fact remains that in man they have not even become subspecies. An illustration not derived from the book under consideration may make this clearer.

In the hammocks of the Everglades there occurs a species of highly-colored land snail. Before certain experimenters, whose enthusiasm outran their intelligence, mixed them up each hammock was characterized by its own type of color form. At first, many of these color forms were given varietal names but when it was realized that the rigorous application of such practice would result in giving a separate name to every individual the nomenclatorial artists began to lose their zeal. Newly discovered individuals that partook of the nature of two recognized races were considered to be hybrids. Note that the difference between a race and a hybrid is merely that the race has a name, and that the fact that it has a name is the result of the accident that it was discovered first. According to this kind of taxonomy, if three forms, B, C, and D, should exist, and that C resemble B in some respects and D in others, C would be considered a hybrid between B and D. But it would be just as logical to consider C as a race, with B and D hybrids between A and C, and between C and E, respectively.

Now Montagu believes, and supplies ample evidence to substantiate his contention, that a similar condition holds in the human species. All men do not look alike, but individual men cannot be assigned to different races because races have not, as yet, been evolved—there are only combinations of genes. Even the races which Blumenback postulated nearly two centuries ago have never existed in a pure form. It is true that not all anthropologists will agree—Sir Arthur Keith maintains a belief in race superiority although completely free of race prejudice in his private life. Montagu is quite fair to Keith and quotes him extensively, but always has an answer for him.

MINORITY PEOPLES IN A NATION AT WAR. *The Annals of The American Academy of Political and Social Science. Volume 223, September, 1942.*

Edited by J. P. Shalloo and Donald Young. Twenty-seven articles by various authors. The American Academy of Political and Social Science, Philadelphia. $2.50 (cloth); $2.00 (paper). 9¼ x 6¼; vii + 276; 1942.

This volume of the Annals is very timely. Only last year upwards of 75,000 American citizens of Japanese ancestry, together with half as many more foreign-born Japanese who would have become citizens years ago except for legal technicalities were evicted from their homes and sent to relocation centers, although so far as the present reviewer has been able to learn only two of these were known to be disloyal to the country of their choice. A mass evacuation of such magnitude can not be carried out without some degree of hardship, as Goethe's *Herrmann und Dorothea* and Longfellow's *Evangeline* bear witness, but the fact that so few voices were raised in protest at the time and that other minority groups of citizens are beginning to ask whose turn will come next is ample evidence of the need for wider circulation of such information as is contained in the twenty-seven essays which the American Academy of Social and Political Science has assembled here.

These essays are concerned with such groups as the Negroes, the Jews, the Indians, the Japanese, and the refugee immigrants. Some of the authors emphasize the part that these minorities are playing in the war effort, but most of them are concerned with the larger question, as to what happens to minorities in a nation that goes to war.

PEOPLES OF THE PHILIPPINES. *Smithsonian Institution War Background Studies Number Four. Publication 3694.*

By Herbert W. Krieger. Smithsonian Institution, City of Washington. Free. 9 x 6; iv + 86 + 24 plates; 1942 (paper).

Of all the peoples of Asia and of the Indonesian island world off its southeastern coast, those living under the banner of the Commonwealth of the Philippines stand alone as beneficiaries of the cultural heritage of the Western World and of the civilizations brought to the islands from eastern lands. Most Americans have observed individual Filipinos going about their business in various capacities and occupations and many of us have learned to distinguish the general appearance of the Filipino from other Orientals. The present handbook offers an excellent opportunity for the average American to obtain a first-hand, working knowledge of the Philippine Islands themselves and of their interesting inhabitants—their past and present, and a glimpse into their probable future. Among the important aspects of the subject which the author discusses are: the land and its people, American contacts, continental affiliations, topography, climate and population, health and sanitation, the rôle of bamboo and rattan, habitations, weapons, food and agriculture, language, head hunting and human sacrifice, and religion. The series of 24 excellent plates and the 4 text figures add immeasurably to the reader's understanding of, and appreciation for, the factual contents of the book. There is a selected bibliography, but no index.

A very well-written and informative little volume, particularly appropriate for present-day reading.

MARRIAGE AND THE FAMILY.

Edited by Howard Becker and Reuben Hill. Twenty-seven Contributors. D. C. Heath and Company, Boston. $4.00. 9¼ x 6; xix + 663; 1942.

This volume, in reality a text-book, contains a mass of information on marriage and family relations contributed by various authorities in their field. In fact 27 collaborators from many institutions in the country have written on their specialties. As the editors remark, since the members of the female sex have some connection with marriage and the family, five of the contributors are women, all of whom are engaged in professional work. Qualified physicians were selected for those portions of the book bearing on the physical aspects of marriage, prenatal care, and childbirth.

The text was planned to combine the better features of marriage and family courses given in American colleges. The material is divided into seven parts, the first of which, entitled Contexts of family life, gives a biological and sociological background of the family. Part two is devoted to topics on preparation for marriage, and part three takes up the physical aspects of married life. The remaining four parts include marriage interactions (adjustment, conflict, money, etc.) and family administration, problems of parenthood, family disorganization, and prospects for the future. Teachers and students alike will find this book of great use.

FIJI: *Little India of the Pacific.*

By John Wesley Coulter. University of Chicago Press, Chicago. $2.00. 9 x 5¾; xiii + 156; 1942.

The subtitle furnishes the key to this interesting study of the economic and political development of Fiji. East Indian migration to Fiji began about 60 years ago. Through continued migration and natural increase the Indian population in Fiji is now almost equal that of the native Fijians (104,872 Fijians and 98,113 Indians as of December 31, 1940). It is the Indians who operate the sugar-cane farms and all the other farms engaged in commercial agriculture: they have practically a monopoly in transportation and in the retail trade.

Thus, from the point of view of commerce and industry, they are the most important element in the life of the islands. In addition, their political power is growing and their birth rate is higher, and the infant and child death rate lower, than that of the natives. To give the reader a better understanding of how it has been possible for the Indian element to attain their present status in the islands, the author describes the older and newer customs of the Fijians, with their communal society and their "It's too nice a day to work" attitude. The author has added some timely suggestions that the authorities concerned with planning the post-war colonial economy in the Pacific may well take into consideration.

CULTURE ELEMENT DISTRIBUTIONS: *XX. Northeast California. Anthropological Records, Volume 7, Number 2.*

By Erminie W. Voegelin. University of California Press, Berkeley. $2.25. 11 x 9½: 47–251 + 1 map; 1942 (paper).

Mrs. Voegelin discusses in the introduction the manner in which she used the element list in collecting information from the various tribes in northeast California. The list contained some 5500 elements and was prepared by Driver, Kroeber and herself. She found a detailed orderly set of questions not only a great time saver but an aid in accuracy.

A large part of the report is taken up with a classified list of the culture element distributions. This should be invaluable to other workers in this field. The latter part of the study is concerned with elements denied by all informants, ethnographic notes on the element list, and an appendix in which a table is given showing the absolute numbers of elements shared and not shared. The author includes in the survey a list of her informants (for each one she gives notes concerning his qualifications) and a bibliography.

RECONNAISSANCE WORK IN THE UPPER RIO GRANDE VALLEY, COLORADO AND NEW MEXICO. *Archaeological Series, Third Paper, Department of Anthropology, University of Denver.*

By E. B. Renaud. University of Denver Press, Denver. 50 cents. 11 x 8¾; 35; 1942 (paper).

The author herein describes in considerable detail his reconnaissance trips in 1942 to old Indian camp sites in the upper Rio Grande Valley. Upwards of 20 sites were visited and potsherds, weapon points, and artifacts collected wherever found. Considerable space is given to a discussion of the Rio Grande points and the variations of this type of weapon.

ZOÖLOGY

SHEARWATERS.

By R. M. Lockley. J. M. Dent and Sons, Ltd., London. $4.00. 8¼ x 5¼; xi + 237; 1942.

What naturalist has not dreamed of owning a small island away from the noise and ugliness of cities; an island with thousands of nesting sea birds, creatures not afraid of man because they have not yet learned to fear him? Of such an island, his home, the author is telling —Skokholm, on the coast of Wales. It is not an easy life, fighting against sea and wind and trying to get feed for the sheep out of the scanty soil.

As long as men could remember the island had been the nesting place of that strange bird of the open ocean, the Manx shearwater. Little was known about its life and habits until the author settled down among them and through years of tedious observation pieced together the epic of their existence. We begin to live with them from the time of their first arrival on the island early in February through the weeks of building and repairing of the burrows in which they will bring up their only young. We see the young shearwaters coming out of their down, when they are deserted by their parents, and alone, driven by hunger, set out to find their way to the sea, struggling with wings and beak and legs made for swimming rather than for walking. In dark nights late in the summer this migration of the young birds to the ocean takes place and woe to the birds which are caught by the dawn away from the shore. The black-backed gull would easily spot the helpless victims.

With the help of identifying rings the author could follow individual birds through the years. One pair, Adam and Ada, came back to the same burrow for four seasons and one female, Caroline, was breeding in her own through eleven summers. It is impossible to give even a hint of the wealth of observations told in beautiful language and charming style.

The ringing of the birds not only helped to identify them at the nest, but also gave knowledge about their travels in search for food and their migration in fall and spring. Thus the author discovered the amazing fact that birds nesting on the coast of Wales flew 600 miles to the Bay of Biscay where they seemed to have their favorite hunting grounds. This explained why some birds used to disappear for several days while their mates were sitting on the nests, and returned fat and glossy to take their place: they had been in the rich and sunny waters of the Bay of Biscay.

Ringing experiments also revealed an astounding homing ability. Even from places where they never could have been before, like Switzerland and Venice, some found their way back to the island in a relatively short time. What was it that guided them even in the densest fog and on the darkest night to their burrows?

The ornithologist will find a great number of inter-

esting and often very exceptional and unique observations. The print and make-up of the book are excellent, and the 20 pages of photographs, some taken by flashlight, greatly add to its value. All those who are interested in the life of animals should not miss this delightful story.

THE IVORY-BILLED WOODPECKER. *Research Report No. 1 of the National Audubon Society.*

By James T. Tanner. National Audubon Socety, New York. $2.50. 10½ x 8; xii + 111; 1942 (paper).

The ivory-billed woodpecker commands attention for two reasons: first, it is the second largest woodpecker in the world, and second, it has rapidly diminished in numbers to a point where its complete extinction is imminent. The problem of its conservation has motivated many groups and societies to attempt remedial measures, but because of the scarcity of knowledge concerning the bird's life habits, no definite program could be advanced. Fortunately we have in this fine report a valuable and timely contribution to the life history of this species with sufficient information to indicate the reasons for its failure to survive.

The writer made extensive and thorough journeys to all known and alleged haunts of the ivory-bill, and according to his conservative estimate there are only 22 individuals left. Half of this number is restricted to the Big Cypress area of Florida and the Singer Tract of Louisiana. It is from intensive studies made in the latter area that Tanner was able to piece together sufficient observations to form some idea of the general behavior of the bird.

The past and present distribution as well as the ecological environment that limits its present haunts are thoroughly discussed. Observations on the nest-life, the caring of the young, and social relationships indicate similarities to that of other woodpeckers. As compared to its closest relative, the pileated woodpecker, the percentage of nesting success is nearly the same, but the larger bird lays fewer eggs, 2.9 to 3.6. This is not the main reason for its failure to increase in numbers, however, as the crux of the matter seems to lie in its food habits. The ivory-bill eats bark-boring insects that enter the trunk 2 to 4 years after the death of the tree. With its strong bill the bird is able to scale the bark off the trunk and reach this food. The pileated digs into trees that have been dead longer and have begun to soften and eats the deeper boring insects. The trees must be 12 to 36 inches as these larger trees have more dead and dying wood. "With modern logging, mature forests of larger, old trees have almost disappeared, and these conditions favorable for the Ivory-billed Woodpecker will very probably never again prevail."

Recommendations are given for conservation of the last few survivors, but unless lumbering is stopped immediately, the fate of this large bird is sealed.

THE CYCLOPHORID OPERCULATE LAND MOLLUSKS OF AMERICA. *United States National Museum Bulletin 181.*

By Carlos de la Torre, Paul Bartsch and Joseph P. E. Morrison. Smithsonian Institution, Washington, D. C. 65 cents. 9½ x 6; 306 + 42 plates. 1942 (paper).

This is the third of a series of monographs dealing with the terrestrial operculates of America. Those who are familiar with the excellent work of de la Torre, Bartsch, and Morrison in the earlier two will know what to expect, and they will not be disappointed in this exhaustive treatise.

Except for the opening page the entire work consists of descriptions and illustrations of genera, subgenera, species, and subspecies—many new names being proposed.

The numerous genera into which this family is now divided are discriminated chiefly by characteristics of the operculum; therefore, when specimens lacking this organ (and many collectors are notoriously careless when it comes to the preservation of the operculum) are sent to the National Museum their generic affiliations cannot be determined. This is especially true of new species. The authors have met this difficulty by devising a new taxonomic category, the pseudogenus, in this case called *Incertcyclus* for the temporary reception of such forms. In the past every writer has been a law unto himself in the generic assignment of indeterminate species, with the result that their synonymies have become cluttered up with irrelevant generic terms of which every systematist has felt in honor bound to perpetuate the memory. The pseudogenus is too young as yet for recognition by the International Commission; let us hope it will not prove too radical for assimilation by that body, for it is a device that might profitably be resorted to in other families than the Cyclophoridae.

The index is the most complete that this reviewer has ever seen; every species and subspecies is listed under its own name as well as under that of its genus.

The authors show a strange tendency toward devising names of hybrid etymology—combining the prefix "cyclo-" with various proper names—for example, Cyclojamaica, Cycloblandia, Cyclovendreysi, Cyclopilsbrya, Cyclohaitia, etc. But this idiosyncrasy does not detract in any way from the systematic significance of the work, which all workers in this group of gastropods will find helpful.

EXPEDITION TO SOUTH-WEST ARABIA 1937–8. *Volume I, Nos. 1–8. Containing the following articles: List and Brief Description of Collecting Stations*, by Hugh Scott and Everard B. Britton; *1. Mammalia: Chiroptera*, by R. W. Hayman; *2. Reptiles and Amphibians*, by H. W. Parker, *3. Freshwater Fishes*, by Ethelwynn Trewavas, *4. South Arabian Non-Marine Mollusca*, by M. Connolly; *5. Arachnida: Scorpiones, Pedipalpi and Solifugae*, by R. J. Whittick; *6. Arachnida: Opiliones*, by C. F. Roewer; *7. Crustacea: Anostraca and Conchostraca*, by J. P. Harding; *8. Crustacea: Isopoda*, by K. H. Barnard.

British Museum (Natural History), London. 7s. 6d. 9¾ x 7½; xiv + 66 + 3 plates + 1 folding map; 1941 (paper).

In this report, the first part to be issued on the British Museum (Natural History) Expedition to South-West Arabia in 1937–1938, brief descriptions are given of the stations where the collections were made by the expedition. The 71 collecting stations are grouped according to the three main political divisions in which the expedition worked: the Colony of Aden proper, the Western Aden Protectorate, and the independent State of the Yemen. A folding map assists the reader in tracing these regions.

Lists and descriptions of the forms collected or reported are grouped under the following headings: mammals, Chiroptera (13 species)—of the four species brought back by the expedition one constitutes an addition to the list for Arabia and the other three were from localities where they had not been reported previously; reptiles (11 species) and amphibians (3 species); fresh-water fishes (4 species)—three of these species, belonging to the family Cyprinidae, are here described and named for the first time; South Arabian nonmarine molluscs (35 species)—nine new forms are included in this group and in addition, descriptions of 8 forms from the Hadhramaut are given, of which one is probably new and two have been hitherto unrecorded from the Arabian peninsula; arachnids, Scorpoines (4), Pedipalpi (3), Solifugae (1), Opiliones (1—a new form); crustaceans, Anostraca (1), Conchostraca (1—a new form); Isopoda (5, of which 4 are new).

Many line drawings show details of these forms.

COLLEGE ZOOLOGY.

By Robert Hegner. The Macmillan Company, New York. $3.75. 9¼ x 6¼; xvii + 817; 1942.

This well-known and widely used general zoology text has received one of its most extensive revisions in the preparation of this 5th edition. As in previous editions the author has largely utilized the "type" method of presentation. The various phyla and classes of animals are discussed in order of their supposed evolution and in each case attention is focused upon one particular form with short references to other members of the group. Limited discussions of physiology, embryology, etc. are included in most cases, but the greatest emphasis is on classification, ecological relationships, and morphology. This edition, however, has been expanded by the addition of chapters on Nutritive processes in animals, Skeletal structures and movement, Coordination and behavior, Reproduction and development, Ecology and geographical distribution, and The origin and history of animal life. In these chapters the material which was previously contained in one chapter on Some zoological principles and theories has been greatly expanded and much material on the functioning of animals has been added. This allocation of chapters to specific functions and principles has made possible a more coordinated and generalized presentation than is possible if function is discussed only in connection with the description of various "type" animals. Several color plates, showing particularly ecological relationships, have also been added, but they appear to contribute little.

On the whole this revision has considerably increased the emphasis on "principles," particularly physiological, and seems to represent a definite advance. It may well be even more widely accepted than previous editions.

LABORATORY DIRECTIONS IN COLLEGE ZOOLOGY. *Third Edition.*

By Henry Lane Bruner. The Macmillan Company, New York. $1.75. 8¼ x 5⅝; xvi + 173; 1942.

The instructor who attempts to organize a course in general zoology faces the difficult task of selecting material from various departments of zoological knowledge and adapting it to students who have entirely different interests. Wide differences of opinion in regard to the content of such a course and the order of treatment are indicated by the variety of courses offered. The experience of the author of this manual has led him to adopt a course which proceeds from simple to complex forms and emphasizes morphology, while at the same time giving due consideration to other aspects of the subject. Exercises on the structure and functions of the cell are followed by work on the protozoa. Studies on mitosis, tissues, organs, gametogenesis and general embryology form an introduction to the metazoa. A series of typical animals, beginning with a simple sponge and ending with the frog, is then studied. Four vertebrates are described, but it is assumed that the frog and dogfish will be more commonly studied, and these have been more fully treated than have the turtle and pigeon. This manual was originally prepared for the zoology course at Butler University and its plan of organization fits it particularly for use with Hegner's *College Zoology*, although it can be adapted to any of the standard college textbooks in the field.

There is adequate material for a full year's work, for a shorter course the instructor can easily make a selection according to his convenience or preference. A complete index concludes this well-written, neatly printed, and substantially-bound volume.

THE CRANE FLIES (TIPULIDAE) OF THE GEORGE RESERVE, MICHIGAN. *Miscellaneous Publications, Museum of Zoology, University of Michigan, No. 53.*

By J. Speed Rogers. University of Michigan Press, Ann Arbor. $1.25. 10 x 6¾; 128 + 8 plates + 1 map; 1942 (paper).

Aside from the fact that this contribution lists a large number of species of crane flies (206) from only 1268 acres, a notable achievement in itself, it also provides invaluable information on the ecology of a relatively little known group of insects. There occur seasonal variations in peak of numbers, some species appearing continuously during the season, others limited to a vernal, estival, serotinal, or autumnal peak, still others having two separate appearances. Specimens taken near the beginning of the peak of abundance were larger and more intensely colored than later specimens. Males predominated at the beginning of the peak while females appeared later.

The habitats of the Reserve are classified and the characteristic crane flies listed. Although often regarded as playing minor rôles in the community, the writer estimates that the total poundage of crane flies living in the Reserve can hardly be less than that of a deer. The reactions and coactions of such a mass of animal life must certainly be of importance in the community. This publication shows the result of careful, systematic collecting over a long period of time and is therefore a very valuable contribution.

LIVES AROUND US. *A Book of Creaturely Biographies. By Alan Devoe. Woodcuts by Frank Utpatel. Creative Age Press, New York.* $2.00. 7¾ x 5¼; 221; 1942.

In this very charming little book of "creaturely biographies" Devoe has given us twenty glimpses into lives around us, "non-human lives that in our obsession with human happenings we are apt to forget to see." He writes with deep and tender feeling of ordinary mammals such as the woodchuck, the shrew, the fox and weasel; the great horned owl, the tiger of the air; the frog-pond with its deep-throated chorus; the turtles; the rattlesnakes; the spiders, trappers of outdoors; and various common insects that sing their songs in the hot fields and dusty tree-tops of our summer season.

To the writer as a naturalist these non-human lives on his up-state New York farm, which he maintains as a wild-life sanctuary, have been profoundly close. They have been his study and his pleasure over a period of years. He suggests that in this day of ours when there is so much chaos to frighten and confuse us, we turn to the unchanging laws of nature to find tranquility, "some bedrocks of certainty to which we may hold, some regions of permanence and security and refreshment for our spirit." The author thinks that "by simply watching with perceptive vision and honest hearts the commonest earth-happenings of every day, we can reassure ourselves of certain changeless things and re-find "a core of permanence in the shifting apparency of our contemporary world."

The volume is artistically illustrated with 22 appropriate and interesting woodcuts by Frank Utpatel.

THE OSTRACODS OF ILLINOIS: *Their Biology and Taxonomy. Illinois Biological Monographs, Volume XIX, Nos. 1–2.*

By W. Clayton Hoff. University of Illinois Press, Urbana. $2.50. 10 x 6¼; 196; 1942 (paper).

The study of American ostracods has been greatly neglected, consisting for the most part of a few scattered, rather incomplete, descriptions of new species. As a result, the writer has had to review the taxonomy of the entire group of fresh-water species in order that their biology may be properly studied. Several new species (11) and some of the older poorly differentiated forms are described, making a total of 39 free-living species for the entire State, exclusive of the waters of Lake Michigan.

Over 700 collections were made from 66 counties in the state. Certain physical factors, as pH and amount of current, controlled the distribution of certain species, while type of bottom and variety of vegetation had no apparent influence. The species were found to fall into four groups, those inhabiting (a) temporary running waters, (b) temporary still waters, (c) permanent still waters, and (d) permanent running waters. Further data are offered on the kind of reproduction in Illinois species, on their geographical as well as ecological distribution, and on their morphology as an aid to future study. Keys and illustrations supplement the detailed descriptions.

FISHES OF WESTERN SOUTH AMERICA. *I. The Intercordilleran and Amazonian Lowlands of Peru. II. The High Pampas of Peru, Bolivia, and Northern Chile. With a Revision of the Peruvian Gymnotidae, and of the Genus Orestias.*

By Carl Eigenmann and William Ray Allen. The University of Kentucky, Lexington. $5.00. 12½ x 9½; xv + 494 + 22 plates + 1 folding map; 1942.

Fishes collected in the highlands of the Peruvian, Chilean, and Bolivian Andes, as well as the eastern slopes of the Andes to the Amazon, in the course of several expeditions to these areas are herein described and annotated. A narrative of the expeditions, a history of ichthyological exploration in Peru, methods of fishing, and South American fish-lore are some of the useful and informative topics discussed. One practical result of these explorations was the introduction of cubé, a fish-poison and insecticide used in the interior of Peru, into the United States. This has subsequently become an important source of rotenone. Another valuable chapter is an ichthyological gazetteer which locates all place names mentioned not only in this volume but also in other publications concerned with this area.

The annotated list consists of 532 species, many of which are illustrated. The genus *Orestias* is reviewed and revised. An extensive bibliography, an index, and a fly map help make this beautifully printed and illustrated volume a valuable contribution to the ichthyology of a still relatively unknown region of the world.

THE OCEANIC TINTINNOINA OF THE PLANKTON GATHERED DURING THE LAST CRUISE OF THE CARNEGIE. *Scientific Results of Cruise VII of the Carnegie during 1928–1929 under Command of Captain J. P. Ault. Biology II. Carnegie Institution of Washington Publication 537.*

By Arthur Shackleton Campbell. Carnegie Institution of Washington. Washington, D. C. $2.50 (cloth); $1.50 (paper); 11¾ x 9; v + 163 + 1 plate. 1942.

This report is primarily a taxonomic and distributional list of the species of Tintinnoina collected on the last ill-fated cruise of the Carnegie in the Atlantic and Pacific Oceans. The Tintinnoina constitute about 40 per cent of the known ciliates, marine and fresh-water, and no sea is without some representative of this suborder. The natural areas of distribution are: the Gulf Stream, the Atlantic drift, the North Sea, the American cold-water region, the Sargasso Sea, the Atlantic equatorial region, the Caribbean Sea, the East Asiatic marginal sea, the Alaskan secondary region, the North Pacific middle latitudes, the California region, the North Pacific trade region, the Pacific equatorial region, the Galapagos region, the region of South Pacific island fields, and the South Pacific middle latitudes. In each of these sixteen areas some Tintinnoina were found.

HANDBOOK OF FROGS AND TOADS: *The Frogs and Toads of the United States and Canada.*

By Anna Allen Wright and Albert Hagen Wright. Comstock Publishing Company, Inc., Ithaca. $3.00. 8½ x 5½; xi + 286; 1942.

This well-known handbook, first published in 1933, has been entirely revised and brought up to date. Like the first edition, there is an introductory portion on the life habits of the frogs, followed by the systematic account. The latter part gives the range, habitat, general appearance, with notes on voice and breeding, for each species and subspecies known to occur in the United States and Canada. Supplemental notes taken from the literature and from the observations of the authors themselves provide additional informative material. Most forms are illustrated by a series of photographs, well known to users of the first edition. The taxonomy and the literature have been brought up to date, the latter especially has been greatly enlarged. A key to the described forms complete this useful volume, indispensable to naturalists or professional herpetologists.

OUTLINES OF ECONOMIC ZOOLOGY. *Fourth Edition.*

By Albert M. Reese. The Blakiston Company, Philadelphia. $3.25. 8¾ x 5¾; xii + 359; 1942.

The usefulness of this book is attested by the appearance of its fourth edition. It embraces the animal world from Protozoa to Primates, and deals with an aspect of zoology not covered in ordinary books on that subject. The author's point of view is that a scientific fact is neither less interesting nor less scientific because it is of value to man. With the growing interest in conservation, accelerated by the exigencies of war, this volume should prove of value to those who seek authoritative information respecting the economic importance—beneficial or otherwise—of some particular animal. There is a reference list of 348 titles.

ZOOLOGICA. *Scientific Contributions of the New York Zoological Society. Volume XXVII, Parts 3 and 4, Numbers 17–19.*

New York Zoological Society. Zoological Park, New York. 10½ x 7; 97–147; 1942 (paper).

This number contains the following papers: The Synonymy of the Garter Snakes (Thamnophis), with Notes on Mexican and Central American Species, by Hobart M. Smith; Membracidae (Homoptera) from British Guiana, by W. D. Funkhouser; A Consideration of Evolutionary Hypotheses in Reference to the Origin of Life, by C. M. Breder, Jr.; Index to Volume XXVII.

TRANSACTIONS OF THE SAN DIEGO SOCIETY OF NATURAL HISTORY. *Vol. 9, Nos. 34, 35, 36, 37 and 38. Foraminifera from the Type Area of the Kreyenhagen Shale of*

California, by J. A. Cushman and S. S. Siegfus; Two New Wrens and a New Jay from Lower California, Mexico; by Laurence M. Huey; *A New Race of the Rusty Sparrow from North Central Sonora, Mexico,* by A. J. van Rossem; *A New Flea of the Genus Ceratophyllus,* by G. F. Augustson; *A Pleistocene Tortoise from the McKittrick Asphalt,* by Loye Miller.

Society of Natural History, San Diego, Calif. 10½ x 6¾; No. 34, 41 + 6 plates; No. 35, 8; No. 36, 2; No. 37, 2; No. 38, 4; 1942 (paper).

UNIVERSITY OF CALIFORNIA PUBLICATIONS IN ZOOLOGY. *Vol. 45, No. 3. Devescovinid Flagellates of Termites. III. The Genera Foaina and Parajoenia,* by Harold Kirby; *Vol. 47, No. 4. The Fossil Birds of California. An Avifauna and Bibliography with Annotations,* by Loye Miller and Ida DeMay; *Vol. 48, No. 1. Mammals of the Big Bend Area of Texas,* by Audrey E. Borell and Monroe D. Bryant.

University of California Press, Berkeley and Los Angeles. Nos. 3 and 4, $1.00. No. 1, 75 cents. 10½ x 6¾; No. 3, 79 + 9 plates; No. 4, 95; No. 1, 62 + 5 plates. 1942 (paper).

NEOTROPICAL LIZARDS IN THE COLLECTION OF THE NATURAL HISTORY MUSEUM OF STANFORD UNIVERSITY. *Stanford University Publications, University Series, Biological Sciences, Volume VIII, No. 2.*

By Charles E. Burt and George S. Myers. Stanford University Press, Stanford. 75 cents. 10 x 6½; 52; 1942 (paper).

THE OHIO RECENT MAMMAL COLLECTION IN THE CLEVELAND MUSEUM OF NATURAL HISTORY. *Scientific Publications of the Cleveland Museum of Natural History, Volume V, No. 6.*

By B. Patterson Bole, Jr. and Philip N. Moulthrop. Cleveland Museum of Natural History, Cleveland. 9¼ x 6½; 83–181; 1942 (paper).

BASIC HORTICULTURE.

By Victor R. Gardner. The Macmillan Company, New York. $3.75. 9⅜ x 6; x + 441; 1942.

In contrast to texts which assume the reader has a thorough botanical background, this book, as its title implies, is designed for students who have had little if any of the botanical groundwork essential for understanding the horticultural principles and practices which have developed from a knowledge of the nature and limitations of the plants concerned.

Starting with an introductory chapter outlining the nature, scope, and importance of horticulture, the author next considers the various categories in which plants may be grouped, not only the conventional divisions of botanical classification according to relationship and phylogeny, but also the agricultural and horticultural groupings according to periods of growth, habit, and method of propagation. The third chapter presents the introductory botanical knowledge of plant structure and growth fundamental to further understanding of the specialized plant parts important in horticultural propagation (chapter 4), after which the environmental factors of temperature (chapter 5), water (chapter 6), light (chapter 7), and nutrients (chapters 8, 9, and 10) are considered in their relation to the development, flowering, and fruiting of horticultural plants. The chapter (11) on growth and fruitfulness covers in 18 pages this complicated and significant interplay of external and internal factors adequately for the use of the student without becoming involved in any of the controversial aspects of this physiological field. A discussion of flower bud differentiation and flowering habits (chapter 12) serves as a fundamental groundwork for the horticultural practices of training and pruning that follow in chapters 13 and 14, while a similar fundamental discussion of flowers, fruits, and seeds (chapter 15) serves as a basis for the detailed and practical treatment of horticultural practices of propagation, whether seminal or vegetative, that follows in chapter 16.

Two chapters (75 pages), one (17) on plant pests and the injuries they cause, discussing physiological disorders, virus, bacterial, and fungous diseases, as well as the depredations of insects; the other (18) covering the control of such ills by cultural methods, poisons, fumigants, sprays, etc., while not, perhaps, adequate in themselves to enable the student successfully to recognize and to combat the many ills which will be his harassing competitors later, will at least enable him to make better use of the wealth of literature on plant ills and their control available from the Department of Agriculture, state experiment stations, and other sources. Three final chapters on the culture of annuals (chapter 19), biennials, herbaceous perennials, and bulbous plants (chapter 20), and woody perennials (chapter 21) conclude the body of the text.

A helpful feature is the inclusion, at the end of each chapter, of problems, projects, and questions which stimulate the student to think for himself in applying to practical problems the knowledge he has gained in each chapter; while a three-page section of 24 general questions and problems at the end of the book similarly will prove practical and useful. A glossary of 11 pages, successfully defining in simple, relatively non-technical phraseology, terms from *abscission* to *xylem*, although consisting in large part of terms that would be familiar to a student who had had some training in botany, comprises also the basic technical vocabulary of horticulture, and hence is of two-fold value to the student who has derived his botanical as well as his horticultural training through this text.

In conclusion, an adequate index of four pages serviceably refers to the subject matter of the text, the pages in which more detailed and comprehensive treatment is given being distinguished by bold-face type.

The book, as befits Macmillan's standards, is well

printed in readable type on heavily sized paper that permits clean, effective printing of the many half-tones in 180 figures that effectively enhance and supplement the text. More than three line drawings might well have been used as illustrations with no loss of effectiveness and with less expense, while if the modified leader, intermediate between the open-center and the leader styles of training, does indeed embrace most of the supposed advantages of the two more extreme styles and has been steadily growing in favor, illustrations of it might advantageously replace some of the several figures of the other two styles.

Written primarily for those without much background in science, the book is simple and direct in presentation, giving the student adequate background and practical knowledge without becoming involved in some of the difficult or controversial questions. Occasionally the choice of words or the method of expression seems somewhat unfortunate. All too frequently, phraseology such as, "He may employ substantially different materials *than* he would use. . . . ", "*Note how* it has rooted at the nodes *and that* upright shoots. . . . ", "An enlarged longitudinal section through a stem *from which* a narrow ring of bark has been removed *and that* has been. . . . ", "Paradise—The name given to a dwarf growing variety or type of apple often used as a stock *and that* has . . . " exemplifies carelessness that either sets a bad example for the student, or disturbs him if, perchance, he is taking Basic English as well as Basic Horticulture. This carelessness extends even to the explanation of the figures, occasionally with startling results, the explanation of figure 7, "Euonomus radicans vegetus set close to a building that is growing naturally as a vine," as it stands implying the neatest horticultural trick of the year, a method of growing houses rather than prefabricating them.

On the whole, the book successfully attains its objective and will prove useful not only at Michigan State College, where the author is Professor of Horticulture, but also in other state colleges and universities, while much of it will be found valuable by the amateur gardener and horticulturist whose interest, whether primarily aesthetic, economic, or gastronomic, in making use of the ground around his home has been stimulated into activity by the shortages and rationings of the present war.

A Textbook of General Botany. *Fourth Edition. By Gilbert M. Smith, Edward M. Gilbert, Richard I. Evans, Benjamin M. Duggar, George S. Bryan and Charles E. Allen. The Macmillan Company, New York.* $4.00. 9¼ x 6; x + 668; 1942.

This most recent (fourth) edition of a text already widely known and of proved value, maintaining as it does the high standards of previous editions, with nearly a hundred additional pages and with many changes and revisions, will be certain of an enthusiastic reception by the many who are familiar with earlier editions, and merits consideration by those who have not used this text in the past.

For the first time since the first edition appeared in 1924, the happy combination of the *sex viri sapientissimi* has been broken by the loss of Professor Overton and the resignation of Professor Denniston, but, as would be expected, the newly added collaborators, Duggar and Evans, ably carry on the traditions of their predecessors. With commendable openness of mind the authors have profited by the criticisms and recommendations of the teachers of botany who have used the book in the past, as is exemplified in their restoration of the Myxomycetes, lamentably omitted from the third edition. An innovation which immediately catches the attention of the reader is the frontispiece; the half-tone portraits of Linnaeus, which have smiled benignly through the first three editions, now being replaced by a modern four-color reproduction of Yellowstone lichens, while a few other color plates will be found in later chapters accompanying subjects that can be most effectively illustrated thereby. Certain new chapters have been added, notably a brief discussion of nine pages on plant diseases caused by various groups or organisms, and a brief survey in 23 pages of the groups of fossil plants of particular interest as forerunners of the present flora, exemplifying the decline of the Gymnosperms and the rise of the Angiosperms in recent times.

There has been some reorganization of material in the first 225 pages which cover the fundamentals: structure, development, and function, based on the type plant chosen for introductory study because of its familiarity; with chapters also on growth and movement and on nuclear and cell division.

The classification of plants (chapter 11) uses the older and generally accepted recognition of four main divisions, while the succeeding discussion (in over 300 pages) of the representatives of these divisions adheres in general to the successful previous plan of a survey of the plant kingdom, with additional material and some revisions bringing the work up to date. A chapter on the reduction of the number of chromosomes, although general in scope, in logical sequence follows the treatment of the Bryophytes as a division, while the new chapter on plant diseases has been inserted immediately after the 50 pages discussing the fungi, a logical location suited to the organization of the discussion of these diseases according to the group of organisms causing them. The new chapter on fossil plants is interpolated immediately after the survey of the plant kingdom, and being thus strategically located after the detailed discussion of the Pteridophyta, the Gymnospermae, and the Angiospermae, it can to better advantage present its brief but effective treatment of the early land plants of the Devonian Psilophytineae through the transitional Carboniferous, Permian, and Triassic floras to

the rapid rise of the Angiosperms from the Jurassic and Lower Cretaceous onward.

The final three chapters on inheritance and variation, on evolution, and on the major regions of vegetation in North America conclude the book as in previous editions, the only notable change here being that the material on the economic significance of plants, instead of being assembled in a separate discussion along with these other general chapters, is now scattered through the text in appropriate locations; e.g. the importance of conifers for buildings, furniture, wood pulp, decoration, telephone and fence poles, railroad ties, naval stores, etc., is now considered under the Coniferales in the survey of the plant kingdom.

The book, as heretofore, is complete, authoritative, and effectively organized. It is free from errors and is a thoroughly functional and usable text. In a volume of this scope, it is of course impossible to include everything, and each reviewer may possibly deplore some omission which to him seems unfortunate. This reviewer's chief regret is the omission, save for one-half page under plant diseases, of the large, difficult, but exceedingly important group of the Fungi Imperfecti, an omission in which, unfortunately, practically all textbooks concur. To be sure, *Penicillium* and *Aspergillus* are discussed briefly under the Ascomycetes, but considering that many of the students now taking botany will soon be encountering imperfect fungi other than *Penicillium* and *Aspergillus* as contaminants in their cultures, as causers of spoilage and of disease, as atopic factors in allergy, as agents of fermentation, etc. further knowledge of this group important in medicine, agriculture, and industry would seem desirable.

To older botanists like myself, it is indicative of the changes which our science has undergone that in this able and up-to-date text, phyllotaxy is not even mentioned, either as an aspect of leaf arrangement and stem morphology in the text or even as a word in the index, while auxins, discussed at some length in the text, are referred to in numerous instances. Perhaps as another example of progress, it might be noted that in this edition the Diatoms have actually won for themselves a place in the table of contents, although still in the position of a sort of appendix to the Brown Algae. It is to be hoped the Chrysophyceae and Xanthophyceae will win a place in later editions beside their economically more important diatom relatives.

As each reviewer considers himself derelict in his duty if he does not point out one or two errors of no particular importance, it might be noted that in figure 218 illustrating *Saprolegnia*, in (a) no papilla of dehiscence is shown, even though the spores are mature, while in (b) the zoospores, although obviously just emerged from the sporangium, are apparently of the secondary type, being reniform, laterally biflagellate, heterokont.

It can be predicted that this fourth edition, like its predecessors, will play an important part in the teaching of botany, a function especially valuable now, when in accelerated schedules the premedical and preservice students must gain their background in biology in rapid, intensive courses that put heavy dependence upon texts.

BOTANY

THE SNOW AND ICE ALGAE OF ALASKA. *Smithsonian Miscellaneous Collections, Volume 101, Number 16.* [*Publication 3683.*]

By Erzsébet Kol. Smithsonian Institution, Washington, D. C. 9⅝ x 6⅛; 36 + 6 plates; 1942 (paper).

At the time the author carried out this investigation (1935–1936) she was a holder of the "Crusade International Fellowship of the American Association of University Women" on leave from the Department of Botany of Franz Joseph University, Kolozsvár, Hungary. During the summer of 1936 she was able to study in the field (on the Alaskan Range, the Wrangell Mountains in the interior, the Chugatch Mountains and the Coast Range) snow-inhabiting organisms. She found that "conditions in Alaska are exceptionally favorable for the growth of organisms in snow and ice, and there is much valuable information to be obtained there by biologists."

Since snow and ice algae cannot be cultivated in warm lowland laboratories and up to the present there have been difficulties to be met in carrying on investigations in mountainous regions on these forms, little is known of their developmental cycle, the rôle which they play in the biological cycle in the areas covered by snow or ice, or what higher organisms they serve as food. The author points out that as the development of phytoplankton of fresh water is influenced by the chemical and physical character of the water so "the comparable factors in what may be termed the cryoenvironment of snow and ice act as the controlling factors in the development of the vegetation there, which we may call the cryovegetation." The upper layers of the snow and ice surfaces carry, besides oxygen, minute particles of decomposing and shattered rock and wind-borne dust. The character, then, of snow and ice surfaces is influenced by the environment. Kol distinguishes two types of cryoenvironments, the silicotroph and the calcitroph types. In addition, changes in the pH "influence the composition of the vegetation . . . just as does the salt content." A table is given showing the results of pH measurements in the different regions investigated.

The main part of the report is taken up with a classification of the cryobionts, and an annotated systematic list of the cryomicroorganisms of Alaskan areas visited. A series of excellent plates show these forms. The author also discusses red snow, ice bloom, and snow fleas (*Isotoma* Collembola) which are found in great abundance.

MICROBIOLOGY AND MAN. *Being an Account of the Diverse Properties and Characteristics of Microorganisms, a Description of the Various Tools and Techniques for Their Handling, and an Inquiry into Their Subtle Relationships to Everyday Life.*

By Jorgen Birkeland. F. S. Crofts and Company, New York. $4.00. 9 x 6; x + 478; 1942.

This book is a well-written introductory text on bacteriology for undergraduate students. The author's aim "to give meaning to facts and not merely to state them" makes the book fascinating and practical. It should have no difficulty in holding the interest of the students.

Unfortunately the title *Microbiology and Man* is misleading. Since only an occasional reference is made to the protozoa and very little attention is given to the yeasts and molds, the term "microbiology" has been applied too broadly. The material presented is essentially limited to the bacteria and filterable viruses. However, if these limitations are realized, it must be admitted that the title will have more appeal to the average student than if the book had been given one of the conventional textbook titles.

The fundamentals of microbiology are presented first, followed by a discussion of the general principles of infection, immunity, and epidemiology. With this information as a background, the student should be well equipped to understand and appreciate the relationship of bacteria and filterable viruses to common infectious diseases and to public health when these are considered in the last two sections of the book. The appendix is devoted to the classification of bacteria. A helpful glossary and a list of reference books and periodicals are included. The text material is adequately illustrated with photographs, figures, and tables.

MICROBIOLOGY OF MEATS.

By L. B. Jensen. The Gerrard Press, Champaign, Illinois. $4.00. 9 x 5¾; xi + 252; 1942.

This book deals with the industrial microbiology of meat foods, and, where necessary, the academic features of bacteriology have been fitted into the jig-saw puzzle of an old industry. The meat-packing industry was well grown before laboratory aid was even remotely considered necessary for guidance and control of processing. Many of the terms used in the book are time-honored, and fit snugly into the philology of this ancient guild. The author believes that the relation of microorganisms to agriculture, medicine, food technology, etc. is important enough, but that studies of activities of economic importance should always go hand-in-hand with fundamental biological processes of microorganisms. The reader will note that under every caption in the book lies a pristine field of microbiological research. The incompleteness of these chapters indicates the extent to which research can aid the industry of the future. The author's presentation of data is that of practical meat operations, i.e. the "flow-sheet" method of times, temperatures, substrates, and number and species of microorganisms. Subject matter discussed includes: effects of sodium nitrate on bacteria in meat, gaseous fermentation in meat products by the genus *Bacillus*, bacteriology of green discoloration in meat, action of microorganisms on fats, a study of ham souring, microbiology of beef, bacon and sausage, bacteriology of spices, salt, sugar, paper and wood, control of microorganisms, and a summary of food poisoning of bacterial origin. The book is thoroughly and extensively documented, the references being given as footnotes throughout. There is an index of authors as well as one of subjects. Presenting a well integrated and complete discussion of the subject, together with practical working data, this book should be of considerable value to food technologists, bacteriologists, meat packers, veterinarians, meat inspectors, public health workers and biochemists, to whom it is recommended.

WILD VIOLETS *of North America.*

By Viola Brainerd Baird with Color Illustrations by F. Schuyler Mathews. Introduction by Herbert L. Mason. University of California Press, Berkeley. $10.00. 10¼ x 6¾; xv + 225; 1942.

This very beautiful volume is a key to the some seventy-seven different species of wild violets of North America north of Mexico. The key is easy to read and conveniently arranged into three sections: I, Mock Pansies; II, True Violets; and III, True Wild Pansies. The pistils have been examined throughout and serve as a basis for classification.

In addition to the structural key, a key to colors is given, based on Ridgway's color standards and color nomenclature. The text is abundantly and superbly illustrated with eighty water color sketches, made in natural color and size, by the artist F. Schuyler Mathews—the first time, according to the author, a complete set of such color plates has been published.

The volume contains a complete bibliography itemizing the violet, the collector of the type specimen, and the type locality when known. A very good index giving the scientific and common names of all the species is included.

It may be of interest to note in passing that the wild violet grows in every state of our union and is probably the best known and loved of all the wild flowers. This key, therefore, will undoubtedly have a wide appeal. The beautiful illustrations alone are worth the price of the book.

PRIMA AND PAPAGO INDIAN AGRICULTURE. *Inter-American Studies I.*

By Edward F. Castetter and Willis H. Bell. University of New Mexico Press, Albuquerque. $3.50. 9 x 6; xv + 245; 1942.

This volume initiates a series of comprehensive and scholarly studies planned with the purpose of presenting the early basis of subsistence of the Indian groups in Latin America and our own Southwest. The material presented in this first volume is based upon field studies made by the authors in the autumn of 1938, 1939 and 1940 among the Pima-Papago of Arizona, supplemented by data obtained from historical, ethnographical and archaeological literature. The various chapters deal with the utilization of native wild plants and native wild animals; cultivated crops; selection, development and ownership of land; agricultural implements; planting (including the Piman and Papago calendars), irrigation and cultivation; harvest, storage and seed selection; and general ceremonial aspects of Piman agriculture. As tobacco is a ceremonial crop, both in its cultivation and utilization, a separate chapter is devoted to the treatment of the practical and ritualistic aspects of its cultivation. A bibliography, an index and a number of illustrations of agricultural implements have been provided.

THE PEATS OF NEW JERSEY AND THEIR UTILIZATION. *Part A. Nature and Origin of Peat, Composition and Utilization. Bulletin 55.*

By Selman A. Waksman. Department of Conservation and Development of the State of New Jersey in Cooperation with the Agricultural Experiment Station, Trenton, N. J. 9 x 6; 155; 1942 (paper).

Although given little publicity, the peat deposits of New Jersey constitute an important natural resource. The domestic demand for this type of material is normally supplied in large part from Germany and Scandinavia, but since these sources have been cut off there has been renewed interest in our local peat deposits. The present work is the first of two projects which when completed will furnish a general description of the nature and origin of peat, and detailed descriptions of all the larger peat deposits in New Jersey and many of the smaller ones. The material here presented includes: the nature, formation and abundance of peat, terminology and causes of confusion, types of peat and systems of classification, climatological, geological and botanical factors involved in peat formation, chemical composition, physical and physico-chemical properties, microbiology of peats—formation, decomposition and subsidence, utilization for agricultural purposes and for industrial uses. The illustrations and the tabular and graphical matter add materially to the value of the report. A carefully-selected bibliography of 339 items and a subject index are appended to this very opportune little book.

FIJIAN PLANT STUDIES, II. *Botanical Results of the 1940–41 Cruise of the "Cheng Ho." In Sargentia: A Continuation of the Contributions from the Arnold Arboretum of Harvard University, I.*

By A. C. Smith and Collaborators. Arnold Arboretum of Harvard University, Jamaica Plain, Mass. $2.50. 10 x 6¾; iv + 148; 1942 (paper).

The title of this new series of contributions from the Arnold Arboretum honors the name of Charles Sprague Sargent, who organized the Arnold Arboretum and served as its first Director from 1872 until his death in 1927.

The greater part of the material on which this first number in the new series is based, was collected in the coastal regions of Vita Levu, the largest of the Fiji islands. Other specimens were obtained in the mountains of Tholo North Province, from the Savu Savu Bay region of Vanua Levu and from a few of the smaller islands. In this number only new and unusual plants are discussed. These include 91 species, 8 varieties, and 2 forms described as new, and 53 species or varieties reported from Fiji for the first time. Of the latter, 17 appear to be indigenous and 36 are weeds or otherwise introduced plants. Families and genera are listed and discussed in the order established in Dalla Torre and Harms, *Genera Siphonogamarum.*

BLACK ROCK FOREST PAPERS. *Volume I. No. 16. Notes on the Resampling of Certain Fertilized Plots,* by R. F. Finn. *No. 17. The Comparative Influence of Leaf Mould and Inorganic Fertilizers on the Growth of Red Oak,* by R. F. Finn and H. H. Tryon. *No. 18. Tests of Chemical Control of Hardwood Sprouts,* by H. H. Tryon and R. F. Finn. *No. 19. Mycorrhizal Inoculation of Soil of Low Fertility,* by R. F. Finn. *No. 20. Improvement Cuttings in Mixed Hardwoods,* by H. H. Tryon and R. F. Finn.

Black Rock Forest, Cornwall-on-the-Hudson, New York. 11 x 8½; 15; 1942 (paper).

MORPHOLOGY

THE VERTEBRATE EYE AND ITS ADAPTIVE RADIATION. *Cranbrook Institute of Science Bulletin No. 19.*

By George Lynn Walls. Cranbrook Press, Bloomfield Hills, Michigan. $6.50. 9 x 6; xiv + 785; 1942.

The ancient Greeks knew no dichotomy between the study of structure and of function. Within the all embracing frame of their fundamental physiological concepts a few anatomical clues sufficed to define in irrefutable terms the function of an organ. Thus the function of the kidneys was to filter the urine from the blood, the function of the brain was to cool the blood. When, after furnishing for almost 2000 years completely

satisfying explanations of all phenomena of health and disease, the physiological concept of the four humors reached its ultimate cataclysm, orthodox anatomy reacted naturally by studying structure for structure's sake. This process, intrinsically as arid as the art for art's sake of Greenwich Village, has netted a vast body of factual data and the dry as dust anatomy courses of current medical school curricula.

Reintegration of the artificially separated study of structure and function has been frequently attempted. The most hopeful effort would appear to lie in those modern studies in which unification of these two fields is sought at the molecular level within the domain of biochemistry, but there are some organs such as the eye, whose function is so unequivocally obvious and whose structure is so obviously related to function as to justify an Aristotelian analysis on the levels of gross anatomy and histology. To quote from the author:

'If the comparative ophthalmologists of the world should ever hold a convention, the first resolution they would pass would say: "Everything in the vertebrate eye means something." Except for the brain there is no other organ in the body of which that can be said. It does not matter in the least whether a liver has three lobes or four, or whether the tip of the heart points north or south, or whether a kidney is long and narrow or short and wide.' That everything in the eye means something is both the thesis which this book attempts to prove and the guiding principle in the selection of topics for discussion. All eyes are not adapted to function under identical circumstances and the variable adaptation of structure to these varying circumstances constitutes the field of data in which the author tests his thesis.

Animals whose activities are limited to daylight hours require eyes of maximal resolving power but not of maximal sensitivity. Nocturnal animals require maximal sensitivity but not maximal resolving power. Since the resolving power of an eye is related to its absolute size, the variation in the size of the eyes of diurnal animals is expected to be much less than the variation in the size of the animal as a whole. Maximal resolution is obtained in eyes with small cornea, pupil, and lens, long focal length, extensive retina, slender photosensitive end organs, as in the primates and diurnal birds. Maximal sensitivity is obtained in eyes with large cornea, pupil, and lens, short focal length, plump photosensitive end organs. The extreme variation in this direction is found in the tubular eyes of certain deep sea fish. Animals that are active both in the daylight and at night require both high sensitivity and high resolving power. This is achieved not only by the presence of a duplex system of photosensitive end organs e.g., rods and cones, but by the presence of organs to shield the too sensitive rods from excessive glare in daylight. Such shielding can be furnished by a highly contracting pupil or by photomechanical movement of pigment about the rods themselves.

The author pursues arguments of this type in respect to the presence of color filters in the eye, the function of the pecten, the control of intraocular pressure, the rôle of color vision, etc., etc. His arguments are always interesting and even when they fail to carry conviction, they are stimulating. Occasionally he puts his tongue in his cheek and tells a "Just so" story, but this is no detriment, for the author obviously had fun in writing this book, and the reader will enjoy it also. Furthermore, the literary style would not be improved by having each paragraph begin with "perhaps" or "possibly." If the evidence is incomplete for proof that is the fault of the subject not of the author, and he presents his surmises on the basis of the evidence that he has found. Naturally every rule has its exceptions but the author has a ready explanation for these too. He argues, for instance, that nocturnal animals have not always been nocturnal, nor diurnal animals always diurnal, but that each species has experienced periodic changes in its mode of life. Herbivorous animals, he contends, become nocturnal to escape their enemies; the predators then become nocturnal to find their food; the prey then becomes diurnal in order better to see its attacker, etc. It is not surprising, therefore, to find in some species atavistic features representative of adaptation to a previous environment. This argument might be greatly strengthened if some quantitative correlation were available between the incidence of these "atavisms" and the duration of the period of the alleged cycles, but no data appear to be available on this point.

Taken as a whole, the author has given substantial validity to his fundamental thesis that "everything in the vertebrate eye means something," but the proof in respect to any particular point can hardly be said to be rigorous. The difficulty of proof of the adaptive significance of any individual feature may be illustrated from the following example taken not from comparative anatomy but from clinical experience with which the reviewer is more familiar. If a person is more nearsighted in one eye than the other, he has difficulty in obtaining simultaneously clear images with both eyes. Even with correcting glasses complete functional symmetry is difficult to obtain. It is easy to show that such a person approaches functional symmetry most closely if he holds his reading matter somewhat toward the side of the more nearsighted eye. Several university professors have told me that they obtained much comfort from this trick once it had been pointed out to them. What is surprising is that very few individuals discover this for themselves. One of my patients who apparently did so was a little girl of decidedly subnormal mentality with an I.Q. of about 60, who habitually reads with her head cocked to one side, like a chicken inspecting a grain of corn, with her more nearsighted eye closest to her book. Now it may be argued, since she

is a very wriggly little person, that her random movements during reading afforded her a higher chance of finding the optimal reading posture than was available to the professors, but it may also be argued that her peculiar posture is not significantly adaptive. After all, little Mary is not a very good reader.

COMPARATIVE VERTEBRATE ANATOMY. *Second Edition. By Libbie Henrietta Hyman. University of Chicago Press, Chicago.* $3.50. 9½ x 6¾; xx + 544; 1942. Theoretically, this volume is a second edition of the author's well-known and widely used *Laboratory Manual for Comparative Vertebrate Anatomy* that appeared in 1922. Actually, it has been so thoroughly revised and expanded that it is essentially a new publication, serving as both text and laboratory manual. As such, it is a welcome addition to the literature of its field; for on the whole it perhaps is the most useful textbook of comparative anatomy that thus far has been written in the English language. Yet, despite its virtues, in some respects it merits serious adverse criticism. This undoubtedly is to be expected when a single author endeavors to embrace such a broad, complex field.

The subject matter is treated in "systems," rather than in the less satisfactory manner of describing "types" in toto. Some of the chapters are outstanding in their merit. That on the nervous system is a far better presentation than is usual in books of this character, and the autonomic system is especially well treated. There is more attempt at correlation of nervous structure and function than is customary in such accounts. The author has avoided any temptation to include details of human anatomy—a subject that can be and is better dealt with elsewhere—and so has escaped a pitfall that has entrapped other writers of comparative anatomical tests.

On the other hand, the illustrations frequently are unsatisfactory. Those of the mammalian skull, the digestive and respiratory systems, the blood vessels, the mammalian musculature, the brain and the ear are all inadequate. Furthermore, figures of the mammalian appendicular skeleton, the musculature of the dogfish, the nerve plexuses of the limbs, and the eye are entirely lacking, although all of these structures are described in considerable detail. The illustrations of the muscular system are especially disappointing. Many are of forms other than those described and indicated for laboratory study. Thus the myology of reptiles is pictured in considerable detail although their dissection is not recommended. The value, indeed the propriety, of including illustrations of the hypothetical disposition of the musculature in fossil forms such as the amphibian *Eryops* and the reptile *Diadectes* well may be questioned. This inspirational type of comparative anatomy has done as much to discredit the science as any other single factor.

The text contains a number of essentially minor errors, of which the following few are random examples: The kangaroo rat is stated to be a marsupial (obviously the rat kangaroo is intended); ordinal characters are ascribed to primates which are not common to the entire order; the name of the Australian anatomist Lightoller consistently is misspelled "Lightroller"; the pleural of "plexus" repeatedly and incorrectly is given as "plexi"; the cerebrospinal fluid is said to differ but little from lymph (thus giving a totally erroneous concept of its nature); the limb and extrinsic eye muscles of tetrapods are said to develop from myotomes (whereas they clearly are derived from unsegmented mesenchyme); and the term "spinal accessory" is used improperly so as to include the whole of the eleventh cranial nerve. There is at least one glaring omission—the reader receives no hint that manus and pes both possess an important complex of intrinsic muscles, although the remainder of the limb musculature is described in often questionable detail. The endocrine organs are treated like step-children, with only passing notice. In view of their recognized importance, their treatment in a separate chapter might not be inadvisable. The reference lists in general are well selected, but some are not up-to-date and certain very important publications are not included.

As a presentation of classical comparative anatomy, and with due consideration of the audience for which it is intended, the book is wholly to be commended. But it is a little distressing to discover that vertebrates still are regarded as primarily segmented organisms, whereas much of their segmentation clearly is of secondary nature; and to find over a page in small type devoted to the profitless question of head segmentation. Surely, as the Walrus said, "The time has come to talk of many things," and to banish from comparative anatomical stock-in-trade the all too numerous "pretty stories" based upon inadequate data or even upon pure fantasy. The ghost of Gegenbaur still haunts the science. If comparative anatomy is to recover from the low esteem into which it has fallen in many quarters and regain its rightful place of importance among the biological sciences, it will have to become—as have other branches of anatomy—something more than a mere fruitless type of descriptive morphology and rid itself of obsolete modes of thinking. Already there are stirrings in that direction, produced by the growing comparative interest in correlation of structure with function. But the methods of genetics, experimental embryology, physiology, and even biochemistry still remain to be utilized for the solution of innumerable significant comparative problems. Thus far they scarcely have influenced the body of comparative anatomical knowledge and thought, as evidenced by the book under review.

A MANUAL OF EXPERIMENTAL EMBRYOLOGY.

By Viktor Hamburger. University of Chicago Press, Chicago. $2.50. 9½ x 6¾; xvii + 213; 1942.

This very excellent manual should be most welcome to teachers of biology who have not had an opportunity to obtain first-hand acquaintance with the methods and materials of experimental embryology, but who realize the value of bringing the student into intimate contact with the living, developing organism in their approach to the study of biology. Contrary to what is usually thought, a large number of classical experiments do not require exceptional manual skill or expensive apparatus and are perfectly suitable for the classroom.

Hamburger has outlined in a beautifully clear manner the technical procedures for about 65 experiments to be done on amphibian embryos, chick embryos, and planarians. In the selection of the experiments he states in the preface that he was guided by practical considerations. Only those elementary experiments were chosen which do not require a high degree of manual skill and which can be done in the limited time of a three-hour laboratory period. (In the appendix the experiments are conveniently arranged in groups according to the technical difficulties involved.) Each experiment or group of experiments is preceded by a brief outline of its theoretical implications. In fact, the theoretical significance of the experiments is strongly emphasized throughout the book. These general remarks serve to integrate the different problems handled. They are not intended as a substitute for lectures or for text books, but rather to stimulate collateral reading. Each experiment or group of experiments is concluded with a bibliography which gives reference to those articles directly related to the experiments under consideration and to pertinent review articles. These should be most valuable to the student.

While the experiments are organized according to a logical plan, they need not be taken up in the laboratory in this particular sequence. Since the technical procedures are described for each experiment and are not dependent on previous experience with other experiments, it is immaterial whether one starts with amphibians, chicks or planarians. The availability of the material will probably be the determining factor in the sequence. A tentative schedule for a one-semester course is given in the Appendix.

The 45 illustrations which accompany the text are extremely clear and well chosen. Biologists in general will be ever grateful, I am sure, to Hamburger for getting published at long last, with Ross Harrison's kind permission, that much referred to and long awaited stage series of *Amblystoma maculatum*.

ANATOMY OF THE HUMAN BODY. *Twenty-fourth Edition Thoroughly Revised.*

By Henry Gray. Edited by Warren H. Lewis. Lea and Febiger, Philadelphia. $12.00. 10¼ x 6½; 1428; 1942.

This splendid and widely used textbook first appeared in 1858, three years before its author's death at the early age of thirty-four. Henry Gray was lecturer on anatomy at St. George's Hospital, London. The first edition contained 750 pages and 363 figures. In its newest edition, 84 years later, this standard work has grown to 1428 pages, illustrated with 1256 engravings of which many are in colors. It is interesting to note that it has been found possible to retain, with but little change, much of the original text.

For this latest revision the editor has been assisted by six distinguished anatomists, namely the Drs. E. T. Engle, J. C. Hinsey, N. L. Hoerr, K. E. Mason, D. M. Rioch, and R. G. Williams, who have incorporated in the chapters representing their various specialities the most recent advances in anatomical knowledge. The current edition retains throughout the systematic arrangement of the subject matter which is familiar to many generations of medical students from the preceding editions. This order of presentation still appears to be most serviceable for the purpose of a reference work devoted to purely descriptive anatomy, dealing chiefly with the macroscopic construction of the body. Of the many, and excellent, new illustrations may be specially mentioned the thirty roentgenograms in the section on surface and topographical anatomy. In general this monumental compilation of anatomical information is worthy of the highest praise. It contains, however, some minor inconsistencies in the treatment of the subject matter, such as the following: "Variations" are referred to in connection with vertebrae and muscles, but not in the sections dealing with other anatomical structures, yet many variations in blood vessels, the skull, etc. are fully as significant and as common as those in muscles. In view of the fact that some phases of neurology, for instance, are discussed in great detail, it is surprising that such characters as dermatoglyphics are not even mentioned. Inasmuch as sex differences in the skull and in the pelvis are specially enumerated (including the very doubtful claim that pelvic sex differences appear early in fetal life), one misses any reference to other secondary sex characters in man.

THE PRINCIPLES OF ANATOMY *as Seen in the Hand. Second Edition.*

By Frederic Wood Jones. The Williams and Wilkins Company, Baltimore, $7.50. 9¼ x 6; x + 415; 1941.

It is very gratifying that this widely-known book has become available again in a second, revised, and considerably enlarged edition twenty-two years after its original appearance. The methodology and the manifold problems of human anatomy are thoroughly illustrated by this discussion of the structures and functions

of the human hand. In contrast to most textbooks of human anatomy this treatise is very stimulating and readable, dealing not only with the average morphological conditions in the adult, but also, and this extensively, with the history of anatomical discovery, with comparative-anatomical, embryological and teratological data, with clinical observations, with the general and special significance of individual variations, and with the importance of studying surface anatomy, including such topics as dermatoglyphics, flexure lines and digital formulae. There are entertaining references to fortune-telling, the hand as expressor of emotional states, good and bad anatomical representation in art, and other unusual topics.

The new edition has been enlarged chiefly by six chapters and twenty text-figures as well as by a bibliography of "fundamental sources." It is regrettable that the latter is quite inadequate, omitting many important papers of the last two decades which should have been considered (especially in the text) in order to bring the new edition really up-to-date. In spite of this shortcoming the volume can be highly recommended to all beginners in the study of human anatomy who have as yet been chiefly impressed (and depressed) by the vast new vocabulary to be learned and need to be shown the benefits from close observation and the wide variety of interests in comprehensive anatomical knowledge.

CHANGES IN THE KNEE JOINT AT VARIOUS AGES WITH PARTICULAR REFERENCE TO THE NATURE AND DEVELOPMENT OF DEGENERATIVE JOINT DISEASE.

By Granville A. Bennett, Hans Waine and Walter Bauer. The Commonwealth Fund, New York. $2.50. 10 x 6¾; vii + 97 + 31 plates; 1942.

Successful treatment of the consequences of disease depends greatly upon an early recognition of abnormal conditions. The latter, in turn, requires a thorough and detailed knowledge of the normal structures and functions. The various rheumatic disorders which affect so frequently our joints are still quite imperfectly understood. Through their interests in these particular diseases the authors of this monograph have been led to investigate the human knee joint in its detailed anatomical construction and this in a considerable series of individuals ranging in age from one month to 90 years. There had been no clinical evidence of articular disease in any of these cases, yet in all individuals older than 20 years there were found clear indications of degenerative joint disease (hypertrophic arthritis). It appears, therefore, that the knee joint remains in an entirely normal state for a surprisingly short period after the completion of its development. The age changes in the normal construction of the knee and the progressive pathological alterations in this joint are carefully described and this macroscopically as well as microscopically. Of the greatest help in this are the many and excellently reproduced photographs. A large part of the book is devoted to a comprehensive review of the literature dealing with degenerative joint disease. This literature is listed in a bibliography of 215 titles.

CATALOGUE OF HUMAN CRANIA IN THE UNITED STATES NATIONAL MUSEUM COLLECTIONS: *Eskimo in General. Proceedings of the United States National Museum, Volume 91, No. 3131.*

By Aleš Hrdlička. Smithsonian Institution, Washington, D. C. 9¼ x 5¼; 169–429; 1942 (paper).

During his years at the Smithsonian Institution Aleš Hrdlička has built up a fine collection of skeletal material on the Eskimo. The collection comprises more than 2,200 crania, many of which are accompanied by the rest of the skeleton.

In the present catalogue are given the catalogue number of each cranium, locality where collected, sex, approximate age, deformation, and numerous skull measurements. Only the true Eskimo are included in this collection but the material represents almost the entire range of their habitat—from Greenland and Labrador to western Alaska. Hrdlička finds a possibility that the ancestry of the Eskimo may not have been a homogeneous group, but he believes that any changes or mixtures took place far back in the original habitat of the peoples, probably in Arctic Asia.

The material and data which this indefatigable and careful worker has accumulated on the Eskimo, as well as on other groups of Alaskan peoples, extinct and recent, form a remarkable and invaluable anthropological record of the northern inhabitants of this continent.

THE SKELETO-MUSCULAR MECHANISMS OF THE HONEY BEE. *Smithsonian Miscellaneous Collections, Volume 103, Number 2.* [*Publication 3688.*]

By R. E. Snodgrass. Smithsonian Institution, Washington, D. C. 9½ x 6¾; 120; 1942 (paper).

The writer feels that the skeletal structure of an insect cannot be fully understood without observing its correlation with the muscular system. However, most insect anatomy has been built on the study of the skeletal hard parts under the mistaken assumption that the sclerites are the fundamental elements of the skeletal organization. Most sclerites are recent developments in the evolution of skeletal mechanisms. Insertion points of muscle seldom change and are good evidence for homologizing. It is believed that a study of insect mechanisms, aside from its morphological value, is important to understand the functional activities of the insect. With this point in view, there follows a detailed and thorough description of the bee's skeleto-

muscular anatomy (profusely illustrated) which includes over 200 muscles and their functions.

THE OSTEOLOGY AND MYOLOGY OF THE CALIFORNIA RIVER OTTER.

By Edna M. Fisher. Stanford University Press, Stanford. $1.50. 10 x 6⅝; iii + 66; 1942 (paper). This is an account of the skeleton and musculature of the California river otter, *Lutra canadensis brevipilosus*. The muscles are described in much greater detail than the bones, but their innervations are not given. No comparative data are included.

PHYSIOLOGY AND PATHOLOGY

PROBLEMS OF AGEING. *Biological and Medical Aspects. Second Edition.*

Edited by E. V. Cowdry with Thirty-seven Contributors. Williams & Wilkins, Baltimore. $10.00. 9 x 6; xxxvi + 936; 1942.

"A woman is as old as she looks and a man is old when he stops looking" is the layman's simple view of ageing. Biologists and medical investigators, on the other hand, see in the complex phenomena of ageing a vast variety of important problems which have as yet been solved only in part. With the steady increase in the proportion of elderly people among the populations of all civilized countries problems of ageing have acquired new interest, and work on these problems has become most urgent. Gerontology, as this recently conceived science of ageing is called, is composed of three major fields of investigation, namely that dealing with the problems of the biology of normal senescence, that centering in medical problems of ageing man (geriatrics) and, finally, that concerned with all the socio-economic problems relating to the advanced age groups in human society.

This large volume has collected such a wealth of information and has brought into clear light such a multitude of highly significant problems, all appertaining to the processes of ageing in plants, animals and, particularly, man, that it is quite impossible to condense the contents into a brief review. The splendid, comprehensive organization of the volume can at least be indicated by the following list of the chapter titles and of the distinguished experts who have contributed these papers: Ageing in plants (W. Crocker); Senescence and death in Protozoa and Invertebrates (H. S. Jennings); Ageing of insects (L. O. Howard); Ageing of Vertebrates (T. W. Todd); Human cultural levels (C. Wissler); Longevity in retrospect and in prospect (L. I. Dublin); Cardiovascular system and blood (A. E. Cohn); Lymphatic tissue (E. B. Krumbhaar); Respiratory system (C. C. Macklin and M. T. Macklin); Digestive system (A. C. Ivy); Urinary system (J. R. Oliver); Skeleton and locomotor system (T. W. Todd); Teeth and jaws (H. B. G. Robinson, L. R. Boling and B. E. Lischer); Ageing of the skin (F. D. Weidman); The thyroid, pancreatic islets, parathyroids, adrenals, thymus and pituitary (A. J. Carlson); Female reproductive system (E. Allen); The testes and hormones (E. T. Engle); Male secondary sexual organs (R. A. Moore); Ageing of the nervous system (M. Critchley); The eye (J. S. Friedenwald); The ear (S. R. Guild); Ageing of homeostatic mechanisms (W. B. Cannon); Ageing of tissue fluids (E. V. Cowdry); Ageing of individual cells (E. V. Cowdry); Ageing processes considered in relation to tissue susceptibility and resistance (W. deB. Mac Nider), Chemical aspects and the effect of diet upon ageing (C. M. McCay); Histochemical changes in ageing (O. H. Lowry and A. B. Hastings); Psychological aspects of ageing (W. R. Miles); Psychological guidance for older persons (G. Lawton); Changes in personality and psychosexual phenomena with age (G. V. Hamilton); Ageing from the point of view of the clinician (L. F. Barker); Diagnosis, prophylaxis and treatment in old age (A. Mueller-Deham); Social urgency for research (E. J. Stieglitz); Historical retrospect (C. M. McKay).

The new edition, following the first after only three years, contains nine entirely new chapters and many revisions reflecting the active work and progress in gerontology. The extensive well-selected lists of references, following each chapter, are a most valuable feature of this scholarly and unique work which well deserves the highest recommendation.

EFFECTS OF ALCOHOL ON THE INDIVIDUAL. *A Critical Exposition of Present Knowledge. Volume I. Alcohol Addiction and Chronic Alcoholism.*

Edited by E. M. Jellinek on Behalf of the Scientific Committee of the Research Council on Problems of Alcohol. Yale University Press, New Haven. $4.00. 9¼ x 6; xxiii + 336; 1942.

Ever since our common ancestor celebrated his safe arrival on Mt. Ararat man has been addicted to the use, or rather the abuse, of the fermented juice of the grape and other fruits. Yet until comparatively recent times no comprehensive investigation of the effect of alcoholism on the individual has been undertaken. We have known in a general way that alcohol has a deleterious effect, but we know but little of the specific effects of alcoholic indulgence, or of the specific factors that "drive a man to drink." To remedy this lack, the Research Council on Problems of Alcohol was organized a few years ago. Its members are representative of the fields of medicine, religion, government, education, industry, and business. It is financed by the Carnegie Foundation and affiliated with the American Association for the Advancement of Science, and has under-

taken an unemotional and unprejudiced attempt to discover the truth.

The magnitude of this task may best be judged by the fact that this volume is only the first of a projected set of three, and that when the complete set appears it will contain nothing but the analysis of previously made researches. No controlled experimentation, or original research of any other kind, is as yet contemplated. And no attempt is to be made to study the history of the problem. If this were done it would involve the examination of a bibliography of approximately 100,000 titles, many of which are pure propaganda, and only a few of which have really scientific value. As it is, 3500 titles have been digested to form the basis of the present report. As far as one can judge from the 32 pages of bibliography and 12 pages of index most of these are observational, so that there is probably little of an experimental nature in the present volume.

The book is divided into two parts. The first considers the effects of alcoholism on mental disorders, the second its effect on nervous, nutritional, and hepatic diseases. Volume II is to deal with germ damage, the literature of which is partly statistical and partly experimental, and Volume III with the magnitude of the problem in terms of incidence. The effect of alcoholism on the family, criminality, poverty, and industry will not be covered at all, since they are effects on society and this investigation is confined to effects on the individual.

The conclusion reached, by the evidence presented in this volume, is that there is a high degree of association between alcoholism and all the diseases studied, especially the mental diseases, but that a causal connection has not yet been proved.

THE TIME OF MY LIFE. *A Frontier Doctor in Alaska. By Harry Carlos de Vighne. J. B. Lippincott Company, Philadelphia.* $3.00. 8⅜ x 5¼; 336; 1942.

This autobiography can well be classed as a success story, for from the humble beginning of an orphan on the Bowery of New York City to Health Commissioner of the Territory of Alaska lies the exciting adventures of this Cuban boy. In addition, the book is also a picturization of Alaska when it was the "last frontier" of the Indians and Eskimos and their poorly constructed villages and mining camps and of pioneer medical practice under the most primitive conditions.

At the age of eight years, Harry C. DeVighne became an orphan through the mysterious death of his father and mother. He thus began to sell papers on the streets for several years until he was gathered, with twenty-nine other homeless boys, to be shipped out of New York, to become the foster son of an Iowa farmer. His restless disposition carried him farther west into the Black Hills Indian country and later again carried him to St. Louis where he gained his first interest in medicine as protégé of a brilliant but disreputable physician. This interest was soon displaced when he became a sailor on a freighter filibustering arms to Cuba at the outbreak of the Spanish-American War.

The position first as handy-man in an asylum and later more important work in the same institution permitted DeVighne to regain his interest in, and preparation for, medicine. After graduating in medicine, he received the assignment of making a sanitary survey in Alaska preliminary to establishing medical service for the Indians and Eskimos. Completing this he settled down to a general practice which continued for over thirty years. There are the usual incidents concerning medicine and its practice among a primitive people along with an interesting study of the transition period from Alaska's isolation to the modern strategic outpost of today.

Although this book cannot be classed as outstanding, the author's life story is a commendable example of achievement and does show what a person with ambition can accomplish in spite of a most humble beginning. The book will appeal to certain readers interested in Alaska who like to acquire information through the personal experiences of a pioneer such as DeVighne was.

MEDICAL PARASITOLOGY. *By James T. Culbertson. Columbia University Press, New York.* $4.25. 9 x 6; xii + 285; 1942.

When an experienced scientist is able to write a simplified text on a complex subject, he should be congratulated. It is frequently difficult to eliminate the minor controversial details which are interesting to the specialist but only thought-entangling to the person unacquainted with the subject. As stated in the preface, the purpose of this book is "to supply a small book useful chiefly to medical students and medical practitioners, in which these persons will find a résumé of the significant information upon the animal parasites of medical importance." Dr. Culbertson has accomplished that which he undertook to do.

There are four major divisions to the text. The first division discusses the general principles and the host-parasite relationships that are involved in human parasitology. The next two divisions present the diseases produced by protozoan and helminth parasites respectively. In the fourth division, the arthropods that produce or transmit human diseases are considered. The appendix summarizes the technical methods that are frequently used in handling parasitological material in the laboratory. The subject matter is well organized and is written in a pleasing style. No specific references are made to the original literature, but a list of reference books on parasitology is given.

The most attractive feature of the book is the fine collection of plates. The photographs that compose the plates are excellent: unfortunately some of them have

been labelled incorrectly, but the mistakes should be apparent after reading the text. The drawn figures are not particularly well done, although they do serve their purpose. There are seven helpful tables that summarize various aspects of human parasitology—for instance, geographical distribution, transmission, and chemotherapy of the numerous diseases.

OCCUPATIONAL DISEASES. *Diagnosis, Medicolegal Aspects and Treatment.*

By Rutherford T. Johnstone. W. B. Saunders Company, Philadelphia and London. $7.50. 9⅛ x 6; xiii + 558, 1942.

The recognition of diseases associated with certain occupations is said to be almost as old as the beginnings of medicine. It was not, however, until comparatively recent times that any large-scale attempt has been made to prevent and control the conditions which give rise to such health hazards. The fundamental aim of this book is to outline a basis for the diagnosis and treatment of the more common occupational diseases, to interpret the medicolegal phase, and to offer from experience the expected disability. The presentation of the problem and the arrangement of the material have been designed to meet the needs of the general practitioner, but the medical student has not been lost sight of in this design. The author makes no apology for the simplicity of his presentation, apparently feeling that many practitioners want to know more about the common earmarks of these occupational diseases and how to consider their medicolegal aspects. Of those substances which offer a hazard to health, the hydrocarbons, which comprise most of the solvents, have been roughly grouped as solvents rather than in the aliphatic or aromatic series. Those substances which are most prevalent or most injurious to health, such as benzene, lead, carbon monoxide, carbon tetrachloride, or silica, have received comprehensive consideration. Treatment is given in detail.

Interestingly enough, the material and experience which form the background for this book have been provided by a clinic, whose annual admissions exceed 11,000 patients, and which, for twenty-five years, has been devoted to a surgical and medical industrial service. The excellent and well-chosen illustrations, including color plates, are a distinct feature of the book, adding much to its value. Lists of references are given at the end of the chapters. The appendix contains a table of toxic thresholds of common industrial substances. A complete index concludes the volume.

A treatise which should enjoy a wide acceptance among industrial physicians, surgeons, and engineers, physiological hygienists, and all others interested in the problem of occupational diseases.

ADVENTURES IN BLOOD TRANSFUSION.

By Bertram N. Bernheim. Smith and Durrell, New York. $2.50. 8 x 5¼; xxviii + 182; 1942.

Here is the thrilling story of blood transfusion clearly and nontechnically related by one who is exceptionally well qualified to tell it. The author, a pioneer in the field, has witnessed the development of this new technique of medicine and surgery, and at the same time, has been a very active participant in the unfolding of this unique drama of life and death. The author's interpretation of certain historical features of blood transfusion is particularly interesting and informative. The gradual development and improvement in the transfusion apparatus and methods, the trials of the early donors and the evolvement of the donor-system, the very conservative attitude and even skepticism of the medical profession and the public at large, the use of tests for blood compatibility, and the ever-expanding field of transfusion are all recounted in these pages. A number of interesting and illustrative case histories are given, one of the most unusual being that of the daughter of an ex-President of the United States who could only be transfused after her anger was aroused—this caused the great vein of the neck to stand out prominently, thus making the blood vessel available as a portal of entry. Few people probably have any idea of the vicissitudes which plagued the art of transfusion through the years, and one wonders why the early investigators even ventured to continue with experiments in the face of such continuous opposition and crushing defeats. The subject is brought right up to the last minute with the discussions of plasma transfusions, powdered and frozen plasma, the use of transfusion in the treatment of shock, blood banks, and the possible use of animal blood and synthetic plasma. Written in popular vein, the book deserves a wide reading among all those who wish to be well-informed on the subject. The bibliography is given in the form of footnotes. There is no index.

HEALTH FACTS FOR COLLEGE STUDENTS. *A Textbook of Individual and Community Health. Fourth Edition, Revised and Enlarged.*

By Maude Lee Etheredge. Foreword by Ray Lyman Wilbur. W. B. Saunders Company, Philadelphia. $2.25. 7¾ x 5¼; xiii + 379; 1942.

With the perplexities of modern life, augmented manifoldly by the world crisis, America is confronted with increased health problems. Health knowledge and daily practice of healthful living become necessities for students in the prevention of disease and the promotion of health. This fourth edition of a very successful textbook has been completely revised and prepared with careful consideration of the facts which the medical profession has accepted in the building of health and the

prevention of disease and accidents. The text is aimed at helping the student to derive the utmost in personal development—both physical and mental. In the present edition there is a noticeable increase in the social emphasis of the subjects discussed, and much material has been added that applies directly to the health needs of the present emergency. New and modern material has also been added on vitamins, adequate diets under emergency conditions, the phenomenon of sleep, blood transfusions and plasma banks, the effects of high altitude, the newer therapeutic agents such as the sulfonamides, and the public health problem in the community and in industry. There are new discussions of cosmetics, care of the skin and nails, acne, and a greatly expanded treatment of friendship, love, marriage, parenthood, and the home.

The well-chosen illustrations give added value to the book, but it is unfortunate that they are not more numerous. The chapter on first aid is particularly timely and useful. The book concludes with a comprehensive bibliography and a complete index. There is every reason to expect that this volume will achieve a popularity and acceptance equal to or even greater than that of previous editions.

MEMOIRS OF A GUINEA PIG *or Eight Years in a Doctor's Waiting Room.*

By Howard Vincent O'Brien. Illustrated by Robert Mills. G. P. Putnam's Sons, New York. $2.00. 7⅝ x 5¼; 238; 1942.

This is a truly delightful book, the kind that will brighten up the dullest evening. While written in a rather whimsical vein, the book nevertheless has much in it that is factual and informative, and the casual reader, in addition to being entertained, will leave the book with some pretty sound information about medicine and doctors. The author, a widely-read newspaper columnist, was leading a perfectly normal and healthy life, and then he began to notice specks before his eyes, and he decided on a general physical examination. It didn't prove anything, but it started him on a tour of doctor's offices, and he became a guinea pig in theory and in practice. He was subjected to shock therapy, heat therapy, tests for allergies, manipulation of the feet à la Dr. Locke, vitamins, osteopathy, dentistry, intestinal treatment, chiropractic and gall-bladder treatments. One of the most astonishing chapters is entitled "Arsenic in the stratosphere," and recounts a cure for sinusitis based on a balloon ascension, with further notes about the doctor who wanted a lock of his hair to test for arsenic. The Guinea Pig admits, willingly, that many of the things tried on him have helped others, before and since, and he concludes his saga with some very wise remarks in a good-natured vein on doctors and how to choose them in a chapter entitled "The care and feeding of doctors." It is a pleasure to heartily recommend this diverting book to laymen and scientists alike as a bright spot in a war-beclouded literary atmosphere. The excellent drawings by Robert Mills add much to the enjoyment of the book. There is neither bibliography nor index, and, in fact, one has need of none.

NUTRITION AND THE WAR. *Second Edition, Revised and Enlarged.*

By Geoffrey Bourne. Cambridge, at the University Press. $1.50. 7⅛ x 4¾; 148; 1942.

With food rationing already among us, and with considerably more impending, many individuals are beginning to wonder about the best ways to expend their money and ration points. As a nation, we have become largely conscious—although often in too vague a manner—of the relative nutritive values of foods. Yet despite the reams that have been written upon the subject, there are few sources of comprehensive and authoritative information available to the intelligent layman. Such information is supplied in the present volume, and in a simple and readable manner. Although written primarily for a British audience, it will be no less useful to an American.

The sections on energy and food, proteins, fats and carbohydrates, vitamins, and minerals contain all the information necessary to a basic understanding of nutrition and digestion. Nutrition in war time is treated in a separate chapter. Sixty pages are devoted to analyses of a long list of foodstuffs with respect to their nutritional and energy values. Some of the terms used, as for certain cuts of meats and for various vegetables, will be unfamiliar to most Americans, but this does not seriously impair the usefulness of the list.

ANNUAL REPORT FOR THE YEAR 1941. DIVISION OF TUBERCULOSIS CONTROL. *The Bulletin of the British Columbia Board of Health. Volume 12, Appendix No. 1, 1942.*

By W. H. Hatfield. Provincial Board of Health, Victoria, B. C. 10¾ x 8⅝; 94 (paper).

This bulletin includes descriptive, tabular, statistical and pictorial presentations of the efforts being made in this particular province of Canada against the ravages of tuberculosis. The introduction discusses staff changes, institutions, stationary and travelling clinics, case findings, records, health education, rehabilitation, district nursing and social service, and legislation. The statistical section of the report gives a great variety of tables, charts and graphs illustrating the admissions to and discharges from institutions, clinics, tuberculin testing, new cases examined, notifications of tuberculo-

sis by age groups, sex and diagnosis, tuberculosis mortality by area, city and sex, and the death rates per 100,000 population. Next in order comes a series of maps demonstrating the old and new cases of tuberculosis in the different population groups, and the mortality rates by statistical areas. Finally there is a special group of charts of various types graphically showing institutional patient days, admissions and discharge, x-ray examinations, the percentage of tuberculosis found in each of the principal racial groups, new and old cases examined by all clinics, total deaths from the disease, and other information of value and interest to the vital statistician and human biologist. One is impressed with the completeness and exactness of this report and by the intelligent handling of the data presented. There is no index available.

AN INTRODUCTION TO MATERIA MEDICA AND PHARMACOLOGY. *Third Edition.*

By Hugh Alister McGuigan and Elsie E. Krug. C. V. Mosby Company, St. Louis. $3.50. 8½ x 5½; 779; 1942.

This is a revised edition of a textbook designed particularly for nurses in training, but useful to anyone interested in an elementary knowledge of drugs and their uses. It stresses the practical side of pharmacology. Exercises in arithmetic and in pharmaceutical calculation are included and many problems and questions are presented. Since the book is necessarily abridged, particularly with reference to drug chemistry, numerous references for more extended study are suggested.

The first six chapters may be considered as introductory in nature. They include practical suggestions to nurses in hospital wards, definitions, the types of pharmaceutical preparations, and methods of administering medicines. A short section deals with the general nature and action of drugs. However, greatest emphasis and space is devoted to describing drugs in relation to their effects on specific organs and organ systems of the body. The source, uses, dose, and physiological action of each compound are given. Recent advances, particularly with reference to the sulfa drugs and vitamins, are included. There is a discussion on serums and vaccines, and the book concludes with chapters on the history of materia medica and on drug legislation.

MANUAL OF WAR-TIME HYGIENE. *Supplement to a College Textbook of Hygiene.*

By Dean Franklin Smiley and Adrian Gordon Gould. The Macmillan Company, New York. $1.00. 8¾ x 5⅝; ii + 86; 1942 (paper).

This pamphlet is intended to provide a brief summary and bibliography of those materials which a college student should add to his regular college hygiene course in order that he may be equipped to meet his health responsibilities as an officer in the Armed Forces or in Civilian Defense in the years immediately following his graduation. The first chapter on military hygiene discusses such matters as fitness for military service, equipment of the soldier, training of the enlisted man, feeding the armed forces, personal hygiene, combating infection and the venereal diseases, and recreation in military life. The second chapter on civilian defense is concerned with emergency medical service, air raid warning, decontamination services, and functions of Red Cross chapters. Chapter Three, on war-time first aid, deals with general principles and the treatment of burns, wounds, shock and fractures, transportation of the injured, artificial respiration, and war gases. An excellent and appropriate bibliography is given and a complete index concludes the volume.

This manual, concisely and authoritatively written by recognized leaders in the field, fills a real need and should enjoy a wide circulation not alone among college students, but among the general public as well.

THE MAKING OF A SURGEON. *A Midwestern Chronicle.*

By Ernest V. Smith. The Berndt Printing Company, Fond du Lac, Wisconsin. $3.00. 9 x 5⅞; 344; 1942.

Some books accomplish more than one purpose and this is one of them. It is first the human and very entertaining story of an interesting and unusual life; second, a medical document of significant and absorbing interest to both the layman and the doctor; and third, a profound tribute to those eminent doctor-brothers, William J. and Charles H. Mayo, whose influence lives on not only in the organizations they established, but in the lives of the men they trained.

With appealing directness and a salty sense of humor, the author tells a story of success against great odds, and of accomplishments based on high standards of excellence covering a period of thirty-five years of medical and surgical practice. The large number of interesting and instructive case histories, and the courageous discussion of medical and surgical problems make the book a very worthwhile medical record. The final chapter on "How surgeons are made" is especially interesting.

PRACTICAL BACTERIOLOGY, HAEMATOLOGY AND ANIMAL PARASITOLOGY. *Ninth Edition.*

By E. R. Stitt, Paul W. Clough and Mildred M. Clough. The Blakiston Company, Philadelphia. $7.00. 8¾ x 5⅝; xiii + 961; 1938.

One of the well-known dependable texts which in the present, ninth, edition was rewritten in order to so incorporate the new material with the old as to make a clear, orderly arrangement. The authors have aimed to

coordinate the laboratory and clinical evidence, believing that in this manner the clinician and medical student gain a better insight into the field of diagnosis. They include all the available types of laboratory procedure, and in a section at the end of the volume these are listed, indexed by diseases. Two hundred and eight figures are included in the text and the volume is completely indexed.

BIOCHEMISTRY

ORGANIC REACTIONS. *Volume I.*

Edited by Roger Adams, Werner E. Backmann, Louis F. Fieser, John R. Johnson and H. R. Snyder. John Wiley and Sons, New York; Chapman and Hall, London. $4.00. 9 x 5¾; vii + 391; 1942.

This book is the first volume of a series which is to deal with a wide variety of reactions commonly used in organic synthesis. Each chapter provides a comprehensive survey of a particular reaction and includes a general discussion of the method, modifications, its usefulness in various situations, special precautions, a detailed description of the procedure, expected yields, etc. In all cases the authors have had personal experience with the reactions discussed.

The twelve chapters cover: The Reformatsky reaction, The Arndt-Eistert synthesis, Chloromethylation of aromatic compounds, The amination of heterocyclic bases by alkali amides, The Bucherer reaction, The Elbs reaction, The Clemmensen reduction, The Perkin reaction and related reactions, The acetoacetic ester condensation and certain related reactions, The Mannich reaction, The Fries reaction, and The Jacobsen reaction.

Because descriptions of synthetic methods are so widely scattered in the chemical literature, it is often very difficult for an investigator to find an adequate discussion of even relatively common synthetic methods. The adaptation of a standard reaction to a particular material often requires a great deal of work, but as is pointed out in the preface, "When the results of the investigation are published, the synthesis, which may have required months of work, is usually described without comment." This series of books represents an effort to remedy this situation and bring together in readily available form the information relating to various syntheses. While each chapter cannot claim to be absolutely complete, it does cover most of the uses of a given reaction, and it also provides abundant references to the literature on the subject. The material is easily accessible as the book contains a limited, but adequate, index and a complete table of contents for each chapter.

The volume should serve as an important reference, not only to organic chemists, but also to physiologists and biochemists who have occasional need for synthetic methods. The scope of this first volume is, of course, limited, but it is to be hoped that further volumes will appear at regular intervals.

SEMIMICRO AND MACRO ORGANIC CHEMISTRY. *A Laboratory Manual.*

By Nicholas D. Cheronis. Thomas Y. Crowell Company, New York. $2.75. 8⅜ x 5⅜; xiii + 388 + 70 experiments + report forms.

The attitude of the author in preparing this excellent handbook has been to deviate sufficiently from the traditional methods in organic chemistry to demonstrate the value of his recently developed semimicro technique. This new technique, which is simply that of experimenting with quantities of reagents and apparatus on a scale reduced to 20 percent of that for the regular technique, merits a great deal of consideration in view of its inherent economy and the reduction of laboratory hazards. Realizing that such a radical plan could not possibly be adapted to all circumstances immediately, the author has prudently parallelled his semimicro technique with the standard macro method.

The plan of the book follows somewhat the general pattern for organic laboratory manuals in that it presents first, a number of exercises designed to acquaint the student with the basic principles, techniques, and apparatus essential to the successful study of organic chemistry; second, a group of experiments dealing with the preparation and properties of the simpler organic compounds; and third, a series of problems concerned with the reactions of a number of the more complex compounds as well as with the important group properties and the most striking variations encountered within the same groups of organic substances. The logical and orderly sequence of the experiments, as well as the healthy balance between teacher demonstrations and student experimentations contributes to the adaptability of the handbook to a variety of student needs and interests, and teaching methods. The manual thus achieves its aim in presenting a unified and coordinated subject rather than a series of disjointed exercises.

In addition to the work sheets and the report forms for each experiment provided at the back, the manual carries appendices on laboratory accidents and first aid, apparatus and reagents, critical tables, and reference works for students in organic chemistry. The volume is carefully indexed.

AN OUTLINE OF ORGANIC NITROGEN COMPOUNDS.

By Ed. F. Degering, Carl Bordenca and B. H.Gwynn with the cooperation of W. A. Allen, F. N. Alquist and Others. John S. Swift Co., Inc., Cincinnati. $6.00. 9 x 6¼; 381; 1942.

This volume is based upon notes which the author has accumulated in teaching a course in organic nitrogen

chemistry for the past twelve years. The material is arranged in 36 chapters, some of them quite short. Most of these deal with specific N-containing compounds or groups of compounds, but there are short discussions of more general theoretical problems such as relative negativity, bonds, and isomerism.

Much of the material is presented in outline form and discussions of principles are usually quite brief and direct. The chapters typically begin with a general discussion of the compounds considered, including the probable structure and the bonds involved. This is followed by sections dealing with nomenclature, preparation, physical properties, and reactions.

The volume is essentially written as a text or reference for an advanced course in chemistry of organic nitrogen compounds and should prove very satisfactory for such use. The material is clearly and concisely presented and the complete author and subject indexes make it readily available for reference. It may also prove valuable as a general reference in some cases, but it is hardly complete enough to be classed as a reference work. As the author points out, it is not intended to be comprehensive. References to the literature are frequently given, but they are usually intended to illustrate specific points and do not pretend to be complete.

In general the book is more condensed than most current treatises on organic nitrogen compounds and its uses will be modified accordingly.

THE HORMONES IN HUMAN REPRODUCTION

By George W. Corner. Princeton University Press, Princeton. $2.75. 8½ x 5½; xix + 265; 1942.

This excellent book is based on the Vanuxem Lectures given at Princeton earlier in the year. It is a charming analysis in nine chapters of the structure and function of the male and female human reproductive system. In order to appreciate the broader aspects of the subject, the author summarizes pertinent features of reproduction in lower forms, and free use is made of data from other primates. In spite of the extensive, intimate laboratory experience of the author with the subject matter, he succeeds somehow in maintaining and expressing a refreshing wonder at the beauty and magic of the interrelations of the various parts of the reproductive system. The book should appeal to the educated layman, particularly if the reader should have some biological background.

SEX

CONTRACEPTION AND FERTILITY IN THE SOUTHERN APPALACHIANS.

By Gilbert Wheeler Beebe. Williams and Wilkins Company, Baltimore. $2.50. 8¼ x 5½; xii + 274; 1942.

The exceptionally high fertility and the appallingly low economic status of the rural population of the southern Appalachian region of the United States have presented such a tragic picture to the student of human populations that the region has been dubbed the "problem area" of America. The present volume incorporates the aspirations, problems, successes and failures of the Committee on Maternal Health in their effort to determine the feasibility of controlling one aspect of this unfortunate situation, namely, high fertility.

The impact of a contraceptive service upon the high birth rate of a randomly selected group of some 1300 women residing in a representative county of the area was studied for a period of three years. The reproductive pattern of the group of women prior to admission to the service revealed that their extremely high fertility was directly attributable to the lack of extensive and effective contraceptive practice. As a result of an 80 percent increase in contraceptive practice, and a 30 percent increase in contraceptive efficiency instituted by the service, the live birth rate for the experimental group is reported to have been reduced by about 40 percent. The encouragement gained from the effectiveness of the present contraceptive service is used as a plea for the incorporation of more extensive contraceptive programs in the medical services now conducted by Public Health officials, particularly in the regions of high population pressure such as that of the southern Appalachians.

For the Public Health student interested in instituting such a contraceptive service, this volume will prove an invaluable aid in relation to the organization, the supervision, and the interpretation of the effectiveness of such a service. Of special interest to the population student will be the appended section on methodology in contraception studies in which the contributions of numerous writers on the subject have been critically reviewed.

The work is documented by a bibliography of 150 titles, and is provided with an index.

BIOMETRY

POISSON'S EXPONENTIAL BINOMIAL LIMIT. *Table I. Individual Terms. Table II. Cumulated Terms.*

By E. C. Molina. D. Van Nostrand Company, Inc. New York. $2.75. 11 x 8; 47; 1942 (paper).

The Poisson exponential limit to the point binomial has found wide application in the field of biology, as well as in the physical sciences. In the Bell Telephone System its use in the solution of problems of telephone trunking has led to the preparation of tables which the present volume makes publicly available. The first table gives the individual Poisson term $a^x e^{-a}/\underline{x}$, which is the limit

as n approaches ∞ and p approaches 0 (in such a way that $np = a$), of the probability of an event happening exactly x times in n trials. The table is extended from values of $a = .001$ to $a = 100$. The second table gives the summation of the terms from c to ∞, this being the probability of the event happening at least c times in n trials. A brief introduction gives an explanation of the applications of these tables. The tables should prove very useful to people dealing with problems in the field of simple sampling.

RANDOM SAMPLING DISTRIBUTIONS.

By Alan E. Treloar. Burgess Publishing Company, Minneapolis. $2.25. $10\frac{3}{4}$ x $8\frac{1}{4}$; 94; 1942 (paper).

This book, reproduced in planographed form, is intended less as a formal textbook than as a set of notes to guide the science student in the use of significance tests. It deals with tests on the significance of means, standard deviations, and correlation coefficients. As a guide, it is well adapted to the needs of the thorough student, for it is not just a set of rules, but gives the underlying basis for the rules. It is addressed to the student with only an elementary mathematical training, and the formal presentation is in algebraic terms liberally supplemented with geometry.

Of particular value are the discussions of the interpretation of the significance tests, which keep well in view of the reader the assumptions on which the tests rest. This is especially important in connection with the so-called exact sampling theory which is exact within the realm for which it is derived but may be very inexact in an applied problem which cannot be proved to belong to that realm.

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 5, Number 2, June, 1943.*

Edited by N. Rashevsky. University of Chicago Press, Chicago.

This number contains the following papers: Outline of a New Mathematical Approach to General Biology: II, by N. Rashevsky; Note on the Hamiltonian Principle in Biology and in Physics, by N. Rashevsky; On the Form of Plants and Animals, by N. Rashevsky; A Mechanism of Division of a Cell with an Impermeable Membrane, by H. D. Landahl.

PSYCHOLOGY AND BEHAVIOR

THE SEXUAL CYCLE IN WOMEN. *The Relation Between Ovarian Function and Psychodynamic Processes. Psychosomatic Medicine Monographs, Volume III, Nos. 1 and 2.*

By Therese Benedek and Boris B. Rubenstein. Published with the Sponsorship of the Committee on Problems of Neurotic Behavior, Division of Anthropology and Psychology. National Research Council, Washington, D. C. $3.50. $10\frac{1}{4}$ x $6\frac{3}{4}$; viii + 307; 1942 (paper).

This monograph from the Institute for Psychoanalysis undertakes a correlation of the psychodynamics of the menstrual cycle with the endocrine phases. The study is based on one hundred and fifty-two cycles of fifteen women of childbearing age, who had undertaken psychoanalysis for various personality disorders and were noted as showing in an exaggerated form the common variations in emotional reactions associated with the menstrual cycle.

The psychoanalytic material was judged from day to day for evidences of the sexual reaction, and from this a prediction was made as to the likely endocrine status. The latter was checked by other experimenters by means of the vaginal smear and basal body temperature.

While admitting that other factors influenced the psychoanalytic material, the primary assumption that the dream material, fancies, and psychosomatic symptoms arose from the gonadal status seemed well taken.

The material correlated as follows:

1. Whenever the psychodynamic material showed libidinous desire, activity, or the defenses against it, i.e. anxiety and aggression, the patient was in the phase of estrogen production.

2. Whenever the psychodynamic material was dominated by libidinous narcissism, the indication was for progesterone production.

3. Whenever elimination and hostility were the dominant dynamic tendency, the indication was for a decline of progesterone production, or low hormone level.

It was found that the psychodynamic reactions to hormone change might antedate the vaginal changes by twenty-four to thirty-six hours; and that the psychodynamic reactions to incipient hormone production might be more intense than to a higher level of hormone later on in the cycle.

The psychosomatic motivations of sexual desire appeared as cyclically recurrent phenomena and showed:

1. A strong reaction with acute awareness of sexual stimulation to incipient estrogen production at the beginning of the cycle.

2. If the desire is satisfied, the succeeding emotional manifestations are less intense. If the desire is not satisfied, the reaction to the disappointment may be depression, withdrawal from the partner, so that the manifest desire may not be recognized. There is great variation in the recognition of the sexual desire.

3. Sexual desire in the premenstrual phase often takes on a "quality of extraverted activity and urgency". Sexual feelings are commonly reported, and develop despite low hormone level, and may be interpreted as an expression of general nervous irritation.

The study showed (1) that the pattern of the sexual cycle develops in correspondence with the development of the personality structure, and (2) that the sexual cycle is not the stable and unchanging expression of hormone function. "Sexual behavior represents a functional unity of psyche and soma in woman." The authors stress that hormone change or change in sexual energy is not responsible for all psychic tension. The basic capacities for love, for motherliness, etc., are present before sexual function matures and continue to exist after sexual hormone decline sets in. The authors conclude that their findings give new meaning to Freud's concept of "actual neurosis".

PSYCHOTHERAPY IN MEDICAL PRACTICE.

By Maurice Levine. The Macmillan Company, New York. $3.50; 8⅜ x 5⅝; xiv + 320; 1942.

The introductory chapter of this book is as important to the reader as any of the following chapters. The author clearly outlines his aim in preparing a non-technical treatise in psychotherapy for the general practitioner, medical specialist, and medical student. Psychotherapy, he defines

as the provision by the physician of new life experiences which can influence the patient in the direction of health.

Psychotherapy has a variety of aims, which are overlapping and complementary. Its aim may be the alleviation or cure of symptoms. Its aim may be an increase in life-happiness. Its aim may be an increase in efficiency and productiveness. Its aim may be an improvement in interpersonal relationships. Its aim may be an increase in feelings of security, of self-confidence, of spontaneity, and of self-respect. Its aim may be an increase in maturity.

Obviously, with the rapid strides which have been made in psychotherapeutic treatment in recent times a book of this type is much needed to furnish a clear cut guide to the general practitioner and medical specialist. They are the ones who usually see the first traces of psychiatric disorder in their patients. They are the ones who must judge whether these disorders are of such minor importance that it is possible, out of their own experience, to correct them, or whether the disorders are so acute or in danger of becoming so acute that the patient should be placed in the hands of the specialist.

Fully half of the book is concerned with (A) methods of psychotherapy for the general practitioner, for use in suitable cases. Here Levine lists 24 methods. (B) advanced methods for the general practitioner (who has some added training and aptitude) for use in suitable cases (5 methods): (C) methods for the specialist (10 methods). He emphasizes that these methods are not hard and fast principles—frequently there is overlapping of the various fields, particularly in the A and B groups. The latter part of the book is taken up with three chapters on subjects of special interest—suicide risks, sex and marriage, and the basic attitudes toward children—other topics being omitted to avoid confusion. The final chapter is concerned with a discussion of the main object of psychotherapy—the attainment, for the patient, of normality. Levine outlines the criteria of normality in which emotional maturity "especially in contrast with neurotic character-formation" has an important place. The volume concludes with a chapter on literature for further reading that will be found useful to the physician and a well-arranged index.

The book undoubtedly fulfills its purpose. There will be many in the author's own field, however, who will feel that he has not taken a wholly modern view of psychobiology and that he has leaned rather heavily on the psychoanalyst's point of view.

PERSONALITY AND SEXUALITY OF THE PHYSICALLY HANDICAPPED WOMAN.

By Carney Landis and M. Marjorie Bolles. Paul B. Hoeber, Inc., New York and London. $3.00. 9¼ x 6; xii + 171; 1942.

This study was undertaken in the belief that its results would illuminate the general problem of personality formation and structure in the adult.

The study was carried out on 100 women handicapped by (1) orthopedic disability, or by (2) spastic paralysis, or by (3) chronic cardiac disease, or by (4) epilepsy. The information was obtained through controlled interview, medical history, and by the Rorschach test.

The conclusions are:

"(1) The different types of physical deviation were not distinguished by characteristic or typical personality manifestations. (2) The fact of being handicapped (without regard to what that handicap might be) was associated with hyposexuality and psychological immaturity. (3) Both the age at onset of the handicap and certain characteristics of the early home situation were related to adult personality manifestations. (4) In most cases there was no evidence that psychosexuality was an important component in personality formation."

Autoerotism was rare in childhood. Adolescent urge for independence was not turbulent and often was delayed into the early twenties. Heterosexual orientation occurred in only a few of the girls during late adolescence and adulthood; and this was unrelated to the degree of handicap, but rested on the strong family ties.

The physically normal woman with psychosexual immaturity was found to be disgusted with or repelled by sexual matters. The handicapped woman with psychosexual immaturity, by contrast, was "more apt to have no conscious effect at all concerning sexual matters, not being disturbed by or even concerned with sexuality".

The relative absence of sex drive does not warrant theorizing concerning its repression or suppression. Deficiency is not synonymous with repression.

There was a relative absence of strong object-attachment, without any other evidence of "narcissism".

Vague fears were frequent; religion was important; and a need for security was the most important problem found.

The adequacy of the general adjustment was related to the security and stability of the early home situation, religion, age, intellectual level, psychosexual maturity, degree of handicap, and changes in the degree of handicap.

MIND: *Perception and Thought in Their Constructive Aspects.*

By Paul Schilder. Columbia University Press, New York. $5.00. 8¼ x 5¼; xii + 432; 1942.

The system of psychology expounded in this work is a mixture of behaviorism, gestalt, and psycho-analysis. The author is an advanced student of psychiatry and his conclusions have all been drawn from observations made on subjects whom most students would consider abnormal. But Schilder claims that it is impossible to consider any specific individual as either normal or abnormal, and believes that normality and abnormality can exist in nature only as abstractions. This is because normal and abnormal traits in varying proportions are always present in every personality (cf. "There is so much good in the worst of us, . . .") and that every individual may be normal at one time and abnormal at another.

The author's study of mentally ill persons has led him to accept certain postulates which the student brought up on the classical psychology of William James is likely to find revolutionary. (Incidentally, the name of William James does not occur in the extensive twenty-four page bibliography.) One of these is that the psychology of primitive people is more complex than that of more intellectually advanced persons. Intellectual advancement, he tells us, comes about as a process of specialization, and the specialized mind is essentially simpler than the generalized mind. The evolution of mind, like that of language, seems to be a simplification. The author also rejects Kant's theory of space perception, although the present reviewer is not clear as to the author's intention when he writes "when we touch an object there is always psychologically a space between the object and ourselves."

A peculiar feature of the work is an addiction to unusual words—e.g. oikotropic, eclamptic, erogenous, voyeuristic. The reviewer counted 39 words which he had never heard before. Is it not better to speak in a tongue understood by the people than to use words which cannot be found in the ten thousand and odd pages of the *Century Dictionary*? The use of such words, and of equally esoteric rhetorical structures make it difficult to appraise this book.

The index covers 16 pages and appears to be quite complete.

THE SUBNORMAL ADOLESCENT GIRL.

By Theodora M. Abel and Elaine F. Kinder. Columbia University Press, New York. $2.50. 8½ x 5⅞; xii + 215; 1942.

The subnormal adolescent girl is of great concern to society and much has been done to meet the problems which she creates in a community. However, there is an increasing interest on the part of social workers, teachers, and laymen for information concerning the problems which the subnormal adolescent herself must face. Out of the authors' wide experience in dealing with this class of girls they have written the present book in order to give a presentation of the problems specific to the subnormal girl in day-to-day situations, the difficulties encountered

in her home, where perhaps she may be the only subnormal member of the family; in a school, where she is either having trouble because she is being held back in the grades or is put in special classes when her friends are making normal and successful progress through junior and senior high school; or in the factory, where she is struggling to attain a required speed on a power machine in a short period of time so as to qualify her for trade union membership.

The material is well organized and clearly presented. Numerous case histories are given but in discussing these the authors do not allow themselves to digress from their main theme. Besides discussing the girl of low mentality in the home, the school and industry, the problems which confront the subnormals who have been placed in institutions and those belonging in the seriously maladjustment group are considered. The average subnormal adolescent girl "has her difficulties . . . but even at the worst and in spite of minor disturbances she manages to get along." But a small percentage of girls has not been able to get along and for these "maladjustment itself is a further circumstance with which they must come to terms."

While the larger part of the book is concerned with the difficulties which confront the subnormal girl, the authors also consider the problem from the community's point of view, and have provided a final chapter on the origin of subnormality and its control. A lengthy bibliography and a detailed index conclude the volume.

AN EXPERIMENTAL STUDY IN MEASURING AND MODIFYING ASSERTIVE BEHAVIOR IN YOUNG CHILDREN. *Monographs of the Society for Research in Child Development, Volume VII, No. 1. Serial No. 31.*

By Gertrude E. Chittenden. Society for Research in Child Development, National Research Council, Washington, D. C. $1.00. 9 x 6; 87; 1942 (paper).

The behavior pattern of pre-school children has for some time been recognized as an entity patent to objective analysis, and to a certain degree, to moderate alteration. Since success in the integration of a child with his social group depends on his ability to cooperate with that group, any program of training designed to aid him in making acceptable responses to difficult social situations is worthy of careful study and exploitation.

In the present study an attempt was made to help an undeniably dominating group of pre-school children to interpret social situations and to react to similar situations in their own lives in the light of such interpretation. With the use of dolls in play situations, the children were given the opportunity to resolve difficult social situations objectively. The transfer of interpretation of behavior from the objective situation to the subjective situation for most of the children was quite striking. The essential contribution of the study to the field of social behavior is the fact that children can be taught life, i.e. they do not have to depend entirely upon their limited social equipment, and the trial and error method in discovering what is acceptable and what is not acceptable in human society. Although the number of subjects used for the study was not large, the statistical procedures in handling the data are sound, and the interpretations are well advised.

The study is documented by a list of some 30 publications, and is supplied with numerous tables, charts, and photographs. A table of contents and an appendix of definitions and directions for recording and scoring tests in social behavior are provided.

METHODS FOR THE STUDY OF PERSONALITY IN YOUNG CHILDREN. *Monographs of the Society for Research in Child Development, Volume 6, No. 4, Serial No. 30.*

Edited by Eugene Lerner and Lois Barclay Murphy. Society for Research in Child Development; National Research Council, Washington, D. C. $2.00. 9 x 6; xiii + 289; 1941 (paper).

With the increasing recognition of the fact that adult personality disorders and psychosomatic illnesses can, in many instances, be traced to childhood experiences in personality development, the importance of studying characteristic patterns of acting and feeling among very young children has taken on added significance. In any pioneering work, the paramount job is that of developing methods adapted to the circumstances of the investigation. The four studies included in this preliminary progress report are centered around the development of "projective methods", i.e., situations into which the child can project his total personality in such a manner as to make his reactions capable of objective study and critical analysis.

The point of emphasis running throughout the monograph is that our knowledge of the total personality of pre-school children will be broadened only in proportion to our ability to patiently delineate the features of each child's temperament rather than to reduce the individual to a purely mathematical rating scale. Much of the material presented herein is just such delineation, while the theoretical discussions are kept at a minimum. Photographic illustrations are used in many instances to supplement the written record.

MENTAL ILLNESS: *A Guide for the Family.*

By Edith M. Stern with the collaboration of Samuel W. Hamilton. The Commonwealth Fund, New York. $1.00. 8¼ x 5⅜; xvii + 134; 1942.

Here is a really valuable book of information on what to do when mental illness comes to the family. Practical, sympathetic, it may be read with profit not only by the families of patients but by most physicians.

It stresses the cooperative effort of family and hospital physicians in the care of the mentally ill. Particularly valuable is the plea for complete honesty in the matter of admission.

Only one fault is observed—in the plea for the family always to subordinate their view of the patient and his situation to the physician's. The statistics of recovery in patients discharged from hospital against advice should urge caution. In many ways the families do know the patients better than the physicians ever can. This emphasis, however, is probably necessary, things being as they are, and certainly will do no harm.

This is a thoroughly valuable book to be read by everyone interested in mental disease.

THE PSYCHOLOGY OF EARLY CHILDHOOD: *A Study of Mental Development in the First Years of Life.*

By C. W. Valentine. Methuen and Company, Ltd., London. 22s. 6d. net. 8¾ x 5½; xvi + 557; 1942.

This valuable contribution to the subject of child psychology is based upon the author's study of his own five children up to the age of about 4 or 5 years. His investigations covered a period of some twenty years. The method employed was chiefly biographical, supplemented by experimentation. In the earliest months, observations were made daily, and even hourly in some instances. Consequently, there is a wealth of carefully recorded data respecting the details of development.

The author emerges from his studies as definitely anti-Freudian, and also with evidence against the Gestalt and Behavior theories. Apparently the behavior and personality of the child gradually is built up into a mosaic from a succession of individual units, many of which are innate or instinctive.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

A STUDY OF WAR. *Volumes I and II.* *By Quincy Wright. University of Chicago Press, Chicago.* $15.00. 9 x 6: Volume I: xxiii + 678; Volume II: xvii + 681–1552; 1942.

The tremendous quantity of research that has gone into the making of this book staggers the imagination. Begun in 1926 just as the world was emerging from the penumbra of the first world war, it was completed during the total eclipse by the second. To review it adequately in a short space is impossible; about all that can be done is to review certain phases, always being mindful that another reviewer would have selected other phases.

Some philosophers have held that war originated among the civilized peoples of the eastern Mediterranean, from which point it radiated over the entire world. One difficulty with this theory is that the civilization of pre-Columbian Middle America was somewhat militaristic and it is difficult to believe that the Aztecs and Egyptians ever shared any cultural intercourse. Also, it seems unlikely that one civilization should have acquired the art of war from another without at the same time acquiring the purposes for which wars are fought. According to the author the wars of Middle America were prompted largely by a motive which our Caucasian ancestors never felt—the need for prisoners for sacrificial purposes. On the other hand, the chief causes of war in the old world were a desire for territory, resources, tribute, slaves, or other gain—factors of strangely little influence in the opposite hemisphere.

Of course, the followers of Le Plongeon who believe the original center of dispersion of civilization to have been in America will have no difficulty in postulating a similar origin for war, the absence of human sacrifice among the historic nations accounting adequately for the absence of this factor from the causes of their armed conflicts. But not many scholars would accord to American civilization priority in age over that of the eastern hemisphere. Therefore the assumption is inevitable that wherever civilization has been spontaneously generated, whether in the valleys of the Nile or the Euphrates, the Ganges or the Yang-tse, the highlands of Tiahuanaco or the lowlands about Uaxactun, men have beat their ploughshares into swords and their pruning hooks into spears.

If this assumption be correct, it follows that a unified treatise on warfare must begin far back of the actual beginnings of war, and must consider those traits common to all mankind and the subhuman animals as well, from which we may reasonably suppose war to have been repeatedly spawned. The author finds this original source in animal violence. When man began to traverse the long path that leads upward from "a jelly fish and a saurian" to the "caves where the cave men dwell" he took his animal instincts with him—original sin in the only true sense of that term. Compared with that long period of emergence during which *Homo sapiens* became an artist and a thinker, but not an ethical being, the brief span since the first faint flickering of the inner light began to illumine his conscience seems like but a watch in the night which is past.

The violent proclivities of primitive man found expression in the hunt, crime, and punishment. Civilized man, no less than his primitive forebears, also engages in these activities, but in either case can they be called war. As the author points out, the hunt has more in common with the abbatoir than with the battlefield. Even the strife between two colonies of termites or ants is not strictly homologous to war, since in each anthill the entire population consists of siblings—they are all the offspring of a single queen and her mate. The true analogy is not with a struggle between two groups of united nations each seeking world hegemony, but with a feud between two mountaineer families in Kentucky.

Thus warfare is a peculiarly human invention. Even man himself does not engage in it until he has achieved a fairly considerable degree of advancement. This is the sad part of the story. It seems that as man slowly advances along the trail of civilization subduing the earth as he progresses, he increases not only the possibilities for good but also those for evil, and that until he makes the final conquest, the subjugation of himself, war is likely to remain an inevitable concomitant of civilization. It is like the vermiform appendix, which we would be better off without—but we cannot avoid it because it is a heritage from the days when the human species was growing up, and learning to apply the technique of civilization to his animal instincts.

The author's study of this development is quite revealing. He points out that those animals which rely upon violence to satisfy their normal requirements are more likely to become extinct than are their less aggressive relatives. Similarly, a nation that participates in war, even a defensive war, and even though it may win the victory by crushing its enemies into an unconditional surrender, proportionately shortens its own life.

This reviewer has confined his comments to the biological aspect of war partly because he felt such procedure would be appropriate in a biological periodical, and partly because in several otherwise competent reviews of this work in contemporary publications this aspect has been entirely disregarded. But it would be unfair to the author not to state that his treatment of the political, economic, social, historical, cultural, and religious aspects of his subject constitute the greater and far more important part of the work. For instance, he points out that the decisive battles of the world have generally been characterized by low fatali-

ties. The most destructive battles, on the whole, have been those that have been the least decisive.

The work has some short comings, however. The index, although 51 pages long, is quite inadequate for a work of this size. It should have been about three times this long. The documentation while voluminous is disappointing, for it consists largely of references in footnotes to works difficult of access. Direct quotations would have been more helpful. Also the abbreviation *"loc. cit."* is frequently used to refer to an earlier reference that cannot be found. But these defects are amply compensated for by the appendices in which much source material is set out in detail with statistical tables and graphs.

This is undoubtedly the most thorough study of war ever undertaken, and although the author's conclusions may not meet with universal acceptance the work is likely to become the recognized authority for generations yet unborn.

THE DILEMMA OF SCIENCE.
By William M. Agar. Sheed and Ward, New York. $2.00. 7⅜ x 5; xi + 140. 1941.

Apologists of Christianity make no secret of the fact that the influence of the church on the people of civilized countries has greatly declined in the last two hundred years. They rightly assert that the development of the sciences has contributed much to the breakdown of traditional beliefs. Since science and the results of the scientific method cannot be disputed away, most defenders of historic religions endeavor to prove that all conflicts between knowledge and faith are based on misunderstandings. The clearing of these misunderstandings, they hold, will lead to complete unity of science and religion. This the author, a catholic geologist, undertakes in the *Dilemma of Science*. Had he succeeded in showing that science is in no way opposed to the dogmas of Catholicism much of the modern criticism of Christianity would indeed have been repulsed. We are told from the beginning that the Catholic Church has always appealed to reason and that "although divine teaching goes beyond reason it can never go against it". Furthermore "it seems unreasonable, therefore, to believe, a priori, that there must be Catholic opposition to science." How lightly does one forget today the struggle of the early scientists against the opposition of the church!

What then was the cause of the rift between science and religion? The success of the adolescent natural sciences, we learn, had led to transgression of their limitations. Once the scientist becomes aware of the bounds of his method, knowledge joins hands with faith in a transcendental world. Most of the further discussion is devoted to the retreat of modern science from a crude mechanism and narrow positivism. Indeed the modern scientist knows well enough the limitations of his tools and does no longer claim that the complete understanding of the entire universe and its reduction to a mathematical formula is at hand.

The unification of science and belief is reached thus through a recognition of the limits of science. The boundaries, however, are set by the defender of the dogma. Whenever reason touches the beliefs of Catholicism it has transgressed its natural limitations. Yet the reasoning of the apologist is free to assure that, with the help of divine revelation, it has solved once and for all the essence of man's existence. The author's solution is therefore not a synthesis. Essentially he also holds fast to a separation of science and faith. How could there be a real unity between knowledge of this world and beliefs in a supernatural realm outside and completely independent of nature?

The present crisis and the rise of totalitarian governments are, according to the author, a consequence of the growing materialism and the spreading disbelief. Only the return to the church can stem the attack upon freedom of thought. But, may we trust this precious freedom to the Catholic Church to protect it from suppression and persecution, the church which had been its greatest enemy not so long ago?

The book may strengthen Catholics in their faith by telling them that science does not oppose their beliefs with carefully chosen quotations from Compton, Eddington, Bavink, etc., but it will hardly alter the conviction of the majority of scientists that there can be no unity of modern knowledge with dogmas and superstitions of the past.

The author tells us very little about the solution of concrete problems and the harmonizing of science with dogmas like creation, the miracles, resurrection, etc. However, the book is worth reading as it points out the real dilemma of science: do we have to choose between materialism and scepticism on one side and the sacrifice of the intellect in the flight into the supernatural on the other side, or is a real synthesis between science and religion possible?

SPEAKING OF MAN. *A Biologist Looks at Man. By Michael F. Guyer. Harper and Brothers, New York and London.* $3.50. 9¼ x 5¾; 321; 1942.

Man, in his search for knowledge about the world, about himself and his place in the universe, and in his striving for a richer and better organization of life, is turning more and more to the scientist for an answer. Many scientists have become aware that they have something to contribute not only to the material, but also to the spiritual life of their society. Thus a great many books about man, his immediate and more remote environment, his problems, and ideals have been written recently by physicists, chemists, astronomers, biologists

and others. Like many of this kind of book the present volume makes us aware that being a good scientist is not enough to bring original answers to philosophical, religious, or political problems.

In *Speaking of Man* we find the world view of an investigator and teacher in the biological sciences. He points out that the facts and theories of the science of life greatly influence our thinking and should be considered in the planning of human society. Our dependence on other living organisms renders great economical importance to biological knowledge. Further, the author discusses man's place in nature, the evolution of intelligence, and some aspects of modern psychology. The importance of hormones in human life is stressed and leads the author to visions of the future, faintly reminiscent of Huxley's *Brave New World*, yet more vulgar than witty.

From biology of sex and sex determination we are led to a consideration of virtue. The advice to young men and women on how to chose their mates strikes us as somewhat out of place.

The future of democracy is viewed from the position of the eugenist. Guyer sees a great danger to democracy in the unproportionate reproduction of the "stupid" compared with that of the "intelligent."

The many shortcomings of our system of education are severely criticized by the author, yet we fail to find positive suggestions for improvement. The last chapter is devoted to a discussion of human ideals and religious beliefs. Guyer feels that religion has been a powerful force in human history yet he does not uphold any definite belief and offers no ideas for overcoming the many faults of historic religions. The conflict between science and religion is only briefly touched upon and the author's solution is the familiar way out by complete separation of faith and knowledge.

The biological information distributed throughout the book is on the level of an elementary course in biology. The book is written in a broad conversational style and in completely non-technical language. Those who are interested in the thinking of a modern biologist and in the way he sees man and the universe will be interested in *Speaking of Man*. Those, however, who search for a solution of present day problems, scientific, ethical, and religious, and who would like to penetrate the surface of conventional thinking, will be greatly disappointed.

GEOMORPHOLOGY: *Systematic and Regional.*

By O. D. von Engeln. The Macmillan Company, New York. $4.50. 9¼ x 6¼; xxi + 655; 1942.

The science of geology begins in astronomy with a spiral nebula and breaks off in political geography with a world war. It is no longer possible to specialize in geology; too many diverse fields are covered by that discipline.

The term "geomorphology" covers that division of geology which has for its field the surface of the earth as it exists today, or as it would exist if it was not being constantly modified by human agencies. The changes that man achieves when he digs a canal or builds a dam or ploughs a dust bowl are more noticeable than the more subtle changes wrought by nature when a stream is pirated or a mountain range upheaved, partly because they take place so much more rapidly and partly because they have an economic importance to civilization.

But nature is incessantly at work. In paleontological eras of the past the valleys have been exalted and the mountains and hills made low not once but many times, and the process is always going on. The mills grind slowly, but exceeding small.

The present work is an advanced treatise in which the surface of the earth and the natural influences operating upon it today are dealt with. There is no discussion of cosmic theories to explain the origin of the earth, no attempt to prove that the tide-raising force varies inversely as the cube of the distance, no account of the various forms of life that have arisen, flourished, and disappeared, for all these are outside the field of geomorphology. Instead we find discussions of mountain peaks and drainage systems, of fault blocks and basaltic palisades, of volcanoes and coral reefs, of the difference in regularity of the Atlantic and Pacific coast lines.

The work is abundantly illustrated with maps, drawings, and excellent photographs, mostly of well-known geological features of North America, though the other continents are not neglected. (The photograph of the Rainbow Bridge taken from an aeroplane is not likely to be quickly forgotten.) Each of the 23 chapters has its own bibliography and at the end of the book is an index of 24 pages.

The use of many highly technical terms will prevent many people from reading this book. A glossary would have increased not only its usefulness, but its popularity as well. The literary style is very good, and the thought is clear, so that any intelligent person who wishes to learn something about the world in which he finds himself would enjoy it, provided he could understand it. But the author was not intent on making a general cultural contribution, but had in mind an audience of technically trained geologists for whom a glossary would have been redundant, and consequently the more catholic devotee of nature has been deprived of a cultural treat.

NET IMPRESSIONS.

By A. G. Keller. Yale University Press, New Haven. $3.75. 9 x 6; iv + 349; 1942.

This collection of essays by the distinguished Emeritus Professor of the Science of Society in Yale University represents the "net impressions" of many years. It

covers a variety of subjects, such as the scientific study of society, common sense, science and superstition, religion, fear of death, sex differences, marriage, youth. By the very diversity of the topics, and the fact that they were written at intervals over a period of more than ten years, the individual essays are of uneven interest. Notwithstanding, the author always has something worthwhile to say, and generally does so in a stimulating manner.

Among the most interesting chapters are those that deal with the scope and methods of sociology (or "the science of society," as Keller prefers to call it) and with some of its great figures. The science of society is concerned with human society. It properly studies mores and institutions, but not what goes on in the mind of the individual; it therefore is not concerned with what men think, but with what they do. To accomplish this, society must be studied by scientific methods that approach, as closely as conditions permit, those of the natural sciences, especially biology. Idealism and ideology must be ruled out, as well as philosophers, metaphysicians, and psychologists. Illustrative of the biological approach is the author's exposition of the "adjustment idea," which recognizes the automatic adjustment of human society, a concept adapted from those of organic evolution. Keller severely condemns the construction of utopias, as those of H. G. Wells and Plato, as self-confessed wishfulness. The last-named he regards as having "succeeded in muddling the thinking of generations." The chapter on plans and planning has a timely ring, and many of the remarks and observations are extremely pertinent, if frequently acid. It can be read with profit by all of us who hope that a better and happier world will arise out of the present holocaust.

The final essay deals with the views and accomplishments of some of the outstanding figures of sociology, especially Spencer (whom Keller regards as the founder of sociology as a science), Lippert, and Pareto. These, together with Sumner, "the greatest of all students of human society," form for the author a sort of "big four" in their field. On the other hand, to state it mildly, he has no high opinion of the attainments of Veblen.

PHOTOGRAPHY: *Its Principles and Practice. Fourth Edition.*

By C. B. Neblette with chapters by Ralph H. Braden, Howard C. Colton, Silas M. Thomson and J. W. Gillon. D. Van Nostrand Company, New York. $7.50. 9 x 6; xii + 865; 1942.

The appearance in recent years of books of this type seems to indicate that a true science of photography is at last emerging. Progress in the science of photography had to wait upon the clarification of certain concepts of the nature of matter and energy. Now, order is beginning to appear from among a mass of unrelated phenomena and the practice of photography is tending more and more to become a branch of applied science and less of an empirical craft.

Those readers already familiar with the previous editions will be interested to know that the present volume has been considerably expanded, and the old material rearranged and rewritten. The separation of the sections on the practice of photography from those essentially theoretical is a decided improvement. Several new chapters have been devoted to color photography, much new material has been added to the sections "The theory of the photographic process" and "Tone reproduction," bringing them up to date by including the latest findings.

To readers unfamiliar with this work, the fact that it has come to a fourth edition will show that it has established itself as a standard text. The book is designed for college instruction and deals with the science as well as the practice of photography. An attempt has been made to make the book readable and understandable by any photographer regardless of his scientific background, which is a difficult undertaking. The pictorially minded amateur will find many sections of the book quite understandable, dealing as they do with directions for carrying out one process or another; however, the more scientifically trained photographer will find that the theoretical aspects of photography are quite thoroughly covered.

References to current literature have been extended, but no attempt has been made to compile an extensive bibliography. The subject index has been made more detailed and extensive.

THE ROCKEFELLER FOUNDATION. *Annual Report,* 1941.

By Raymond B. Fosdick. The Rockefeller Foundation, New York. 8¾ x 5¾; 425; 1942 (paper).

During 1941 the appropriations of The Rockefeller Foundation amounted to something over $9,000,000. By far the largest amount, $2,450,000, was in the field of Public Health, to be followed by the Medical Sciences receiving $2,120,000; Natural Sciences, $1,271,000; Social Sciences, $1,227,000; Humanities, $1,020,000; and Progress in China, $154,000. Of the total sum, 74 per cent was for work in the United States and 26 per cent for work in other countries.

The Foundation is engaged in many lines of work that have to due directly with the war. It is furnishing yellow fever vaccine to the Army and Navy, speeding up its research on influenza, malaria and typhus; it has financed the microfilming of countless historical records in England that were in danger of being destroyed, contributed towards special work in brain surgery, and has brought outstanding scholars from Europe to the United States.

The most impressive work reported on and one which is highly important for both South and North America is the eradication of the malaria bearing mosquito, *Anopheles gambiae*, which was brought from Africa to northeastern Brazil, probably by airplane, in the early thirties. During a period of several years *gambiae* succeeded in spreading over an area of 12,000 square miles, creating devasting malaria epidemics. In 1939 an army of over 2000 trained workers was organized under Soper, of The Foundation, to combat the invaders. So efficiently did they perform their work that by the end of 1940 *gambiae* had been completely eradicated. Constant watch for its reappearance is still being kept but throughout 1941, the report states, none was found. All airplanes are now fumigated after leaving Africa and before landing in Brazil. Three dead *gambiae* have been found on arriving airplanes. It would take only one fertilized female to start another epidemic.

NEW TECHNICAL AND COMMERCIAL DICTIONARY.

Compiled by Antonio Perol Guerrero. Editorial Técnica Unida, Brooklyn. $10.00. 9 x 6; ix + 600; 1942.

Rapid commercial and technical developments in the United States and in the more industrialized countries of Europe have resulted in the introduction of many new terms into various languages, particularly English. Since the Spanish Academy, which is the only authority that standardizes the Spanish language, is very slow in recognizing new words, it cannot hope to keep pace with rapid technical developments. This has resulted in the adoption of many English words by Spanish speaking peoples, particularly in Latin America. Geographical distances between the 21 Latin American Republics have resulted in variations in the pronounciations of many of these words which will become ever more confusing if allowed to continue without an attempt at standardization.

This dictionary represents an attempt to facilitate the introduction of new technical and commercial terms into the Spanish language. It contains more than 50,000 words used in the various fields of engineering, mining, textile, and other industries, as well as modern words referring to mechanized warfare and aviation. Words used in business and commerce and conversion tables of weights and measures are included.

No attempt is made to make this an abridged dictionary of the Spanish language in its entirety, and in translating words it must be used in conjunction with an ordinary dictionary. The work is not intended for use by biologists and is weak with reference to biological terms. Nevertheless, in view of the growing importance of Latin America and the Spanish language, it represents a significant and important contribution.

NATURAL HISTORY WITH A CAMERA.

By L. W. Brownell. American Photographic Publishing Company, Boston. $3.75. 9¼ x 6; xi + 292; 1942.

The naturalist, who wishes to keep a record of his discoveries in field and woods, and the photographer, who is searching for new objects, will find much help in this book.

Nature photography is a difficult subject and needs, above all, great patience and love for the out-of-doors. Not less important is a real knowledge of the lives of the many creatures which inhabit our wilds. There is no better way of getting to know plants and animals than by hunting them with a camera. The author's great knowledge of natural history and his experience as photographer make him a most welcome guide.

From month to month Brownell leads us through the woods to ponds and streams and to the sea coast, pointing out the plants and animals as they appear: frogs in March, salamanders and spring flowers in April, birds and their nests in May, all kinds of insects in June, and so on through the seasons of the year.

There is a chapter on equipment and many practical hints are scattered throughout the book. Yet one wishes that the author had told a little more about the photographic side. Color photography, for instance, is not considered at all.

Many of the photographs of the animals and plants illustrate the great wealth of subjects for the camera which we can find around us all the time throughout the year. Most of these are excellent, but lose very much through poor reproduction. It is a pity that not the best technique available was used for publication of these photographs into whose making went so much patience, love, and knowledge.

STEDMAN'S PRACTICAL MEDICAL DICTIONARY *of Words Used in Medicine with Their Derivation and Pronunciation including Dental, Veterinary, Chemical, Botanical, Electrical, Life Insurance and Other Special Terms; Anatomical Tables of Titles in General Use, the Terms Sanctioned by the Basle Anatomical Convention; the New British Anatomical Nomenclature; Pharmaceutical Preparations Official in the United States and British Pharmacopoeias or Contained in the National Formulary; and Comprehensive Lists of Synonyms. Fifteenth Edition Revised with Etymologic and Orthographic Rules.*

By Stanley Thomas Garber. Williams and Wilkins Company, Baltimore. $7.50. 9 x 6; xv + 1257; 1942.

The 15th edition of this authoritative work has been edited by S. T. Garber who collaborated with Stedman in the preceding edition. Although a standard work of this type would not be expected to change radically from one edition to the next, many changes have been made. The references to vitamins have been thor-

oughly revised and many biochemical and chemotherapeutic compounds have been added. The terms in the fields of allergy and hematology have also been revised and the entire terminology relating to bacteria has been revised to conform with the classification proposed by a committee of the Society of American Bacteriologists. In addition, other less extensive alterations have been made to include new terms, to drop some which have become obsolete, and to bring the work as a whole abreast of current medical usage.

Through previous editions this dictionary has come to be accepted as a thoroughly reliable reference for medical and allied terminology, and this latest volume should carry on the tradition.

WALL'S DICTIONARY OF PHOTOGRAPHY *and Reference Book for Amateur and Professional Photographers. Sixteenth Edition.*

Edited by F. J. Mortimer. Sixteenth edition revised and largely rewritten by A. L. M. Sowerby. Iliffe and Sons, Ltd., London. 12s.6d. 6¾ x 4¼; 701; 1942.

The fact that this is the sixteenth edition of an originally well-planned dictionary is proof in itself of the popularity of this type of book. The contents include not only definitions and explanations of photographic terms but also up-to-date formulae and instructions in the use of practically every photographic process known.

Recent developments in chemistry, sensitometry, optics, color and cinematography have all been carefully added to the wealth of information already contained in the volume. To provide space for these additions, articles dealing with processes no longer current have been properly condensed.

According to the preface, "Over fifty articles, including some of the most important, have been revised or extended to bring them more fully up to date or to enhance their usefulness, and several new articles have been added"—but the *Dictionary* as a whole remains a reference-book for the photographer rather than for the scientist or research-worker.

The book was made and printed in England. Its convenient size (7″ x 4½″ x 1¼″) is in its favor. The paper is thin and the type is easily read.

ANNUAL REPORT OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION *Showing the Operations, Expenditures, and Condition of the Institution for the Year Ended June 30, 1941. Publication 3651.*

Smithsonian Institution. United States Government Printing Office, Washington. $2.00. 9 x 5¾; xiii + 596; 1942.

Readers of these columns doubtless need no introduction to this volume. In all ways it follows the standards set up in the previous reports reviewed here in the past several years. As usual, in the General Appendix, are published a number of accounts of scientific discovery and reports of investigations made by collaborators of the Institution. These embrace a considerable range of scientific investigation and discussion. Among those that should be of interest to the biologist are the following: "Vitamins and their occurrence in foods," by Hazel E. Munsell; "Iceland, land of frost and fire," by Vigfus Einarsson; "The genes and the hope of mankind," by Bruce Bliven; "Care of captive animals," by Ernest P. Walker; "The influence of insects on the development of forest protection and forest management," by F. C. Craighead; "Growth hormones in plants," by Kenneth V. Thimann; "Useful algae," by Florence Meier Chase; "Contacts between Iroquois herbalism and colonial medicine," by William N. Fenton; and "The Eskimo child," by Aleš Hrdlička.